UNIVERSITY OF BRISTOL

THE ANNUAL REPORT

OF THE

Agricultural and Horticultural Research Station

(THE NATIONAL FRUIT AND CIDER INSTITUTE)

LONG ASHTON, BRISTOL

1944

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* On Active Service.

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INTRODUCTION.

By T. WALLACE, M.C., D.Sc., F.R.I.C., Director.

The year under review has been marked by the retirement of Dr. T. Loveday, M.A., LL.D., from the post of Vice-Chancellor in the University, which he had occupied since 1922. Throughout his period of service in the University Dr. Loveday had been a member of the Agricultural Committee and, following the resignation of Viscount Bledisloe, P.C., G.C.M.G., K.B.E., from the office of Chairman of the Committee in 1925, Dr. Loveday had filled that position continuously until his retirement. The Department owes much to him for the great contributions he has made to the successful development of the Long Ashton Institute, the Berkeley Square Advisory Centre and the Chipping Campden Station. The Department has indeed been fortunate in having for so many years a Chairman with the personal qualities and special agricultural interests possessed by Dr. Loveday. Not only was he able to bring a wide experience in administration and education to bear on the problems of the Department, but his zeal and enthusiasm for the advancement of agriculture and horticulture and his practical knowledge of these industries enabled him to appreciate the practical value to farmers of the research and advisory work undertaken in the Department. His advice and guidance were often sought by the various Committees and by the Director, and his wise decisions on the difficult problems which have arisen from time to time have been invaluable.

Dr. Loveday's services to Agriculture have not been restricted to his work at Bristol. He served as a member of the Luxmoore Committee on the Agricultural Advisory Services and as Chairman of the Ministry of Agriculture Committee on Veterinary Education, and at present he is Chairman of the Ministry of Agriculture Higher Education Committee and of the Joint Advisory Committee on Agricultural Education. He is thus entering into a very active "agricultural retirement" to undertake work which is very near to his heart, and from which agriculture and farmers will doubtless benefit in years to come. These tasks we are happy to note will be leavened with some practical farming and gardening.

The members of the Committees and the Staff of the Department join in wishing Dr. and Mrs. Loveday many years of happiness in their retirement from academic life.

In view of the unsatisfactory position regarding accommodation within the Department, it is particularly gratifying to report that Capt. W. D. M. Wills, Treasurer of the Department and Chairman of the Finance and Business Sub-Committee, has promised a generous gift to the University of his father's house, "Bracken Hill," Leigh Woods, as a memorial to his father, the late Mr. W. Melville Wills, and has asked that the house shall be used for Agricultural purposes. The house is at present in Government occupation and is not likely to be available until after the war. The gift will do much to solve accommodation problems in the post-war period which otherwise will be very acute.

The research work in the Department has again been directed chiefly to the solution of problems concerned with the Food Production programme of the Ministry of Agriculture, but certain peace-time projects have been con-

tinued and plans have been under consideration for post-war developments in fruit research. Several senior members of the staff have continued to serve on special committees of the Ministry of Agriculture, the Agricultural Research Council and the Agricultural Improvement Council, and of other Government Departments dealing with technical problems.

On the advisory side, work has also been closely concerned with the national schemes of the Ministry of Agriculture, and here again senior members have served on many important Committees. Close collaboration has been maintained with County Technical Development Sub-Committees of the Province through the Chief Advisory Officer, and the advisory staff has worked in close association with members of the County Staffs.

It will be seen that the number of enquiries has again been very large and, although a numerical decrease is recorded, this has not meant a falling off in the volume of work but rather a change in its character in some of the Sections.

A very substantial expansion of the work in Dairy Bacteriology has occurred in connection with the National Milk Testing and Advisory Scheme of which further details are given later.

The Provincial Advisory Conference has continued to function through meetings of its Executive Committee and an Exhibits Committee which, in conjunction with Officers of the Ministry of Agriculture, has prepared a series of exhibits for general use in the counties of the Province and for any other counties where the subjects may apply.

During the year a Committee on Land Classification has been set up under the Reconstruction Research Group of the University to undertake a classification of the land in the counties of Gloucestershire, Somerset and Wiltshire. The Director is Chairman of the Committee and other members of the Department serve on it. The Department Soil Surveyor is responsible for the actual field work which has been undertaken.

At each of the three working centres of the Department good progress can be reported for the year.

The financial position has remained satisfactory, and it is gratifying to record substantial increases in both the number and amount of members' subscriptions. As considerable new expenditure will be necessary in the immediate post-war period in order to resume and develop the normal research activities of the Long Ashton Institute, a large increase in membership is especially desired at the present time, and it is hoped that members will assist in attaining this end by bringing the membership scheme to the notice of their friends and fellow growers.

The articles appearing later in the report have been contributed by the Long Ashton and Berkeley Square Staffs: as in previous years the contributions of the Campden Staff will appear in the report of the Campden Station.

BRISTOL ADVISORY CENTRE.

A summary of the main points in the Advisory work of the Department is given later in the Report and the present account is confined to features which call for special mention.

The administration of the Centre, under the conditions outlined in the previous report, has worked smoothly. Mr. Ling has been able to visit Bristol frequently and Dr. Stewart has obtained a good grasp of the administrative organisation. The added financial work resulting from the expansion of the Milk Testing and Advisory Scheme referred to below has been met by establishing a small branch of the main Department Office at Berkeley Square under

Mr. Leggett with which he keeps in direct touch by frequent visits.

The most important developments during the year have been in connection with the National Milk Testing and Advisory Scheme which has been considerably expanded. The records obtained under the scheme have been centralised at the Advisory Centre, under a special scheme of the Ministry of Agriculture, and this has necessitated the recruitment of special staff and will eventually require increased accommodation. During the year forty-eight creameries have operated licensed laboratories for testing, and the Adviser in Dairy Bacteriology has been responsible for area laboratories in Bristol, Gloucester, Wincanton, Trowbridge and Worcester and a district laboratory at Hereford.

Staff.

Two changes in the senior staff call for mention.

Mr. R. W. Roach, B.Sc., M.R.C.V.S., Assistant Veterinary Advisory Officer, whose appointment was recorded in the last report, resigned to take up an appointment under the New Zealand Government. The vacancy was filled by Mr. B. Rimmer, M.R.C.V.S.

Mr. C. J. Hickman, M.Sc., Research Officer in Mycology of the Agricultural Research Council, who since the outbreak of war has been loaned to the Department and had been in charge of the Field Laboratory at Evesham, resigned on his appointment as Lecturer in Mycology at Birmingham University. His departure necessitated the transfer of Mr. H. E. Croxall, B.Sc., Ph.D., Senior Scientific Assistant in Mycology, to Evesham, and the appointment of a successor to Dr. Croxall at Long Ashton. It is hoped that the vacancy will be filled in March 1945 by Miss M. C. D. Munro, B.Sc., Ph.D., who is at present acting as Assistant Lecturer and Demonstrator in the Department of Botany at the East of Scotland College of Agriculture. The thanks of the Department are due to the Agricultural Research Council for Mr. Hickman's services which have been greatly appreciated by growers in the Evesham district and to Mr. Hickman for the valuable services he has so freely given.

It is with regret that the death is reported in December, 1944, of Mr. L. A. C. Cook, B.A., who for a number of years was a Senior Scientific Assistant to the Adviser in Agricultural Economics. Mr. Cook had rendered valuable services to the Department and was well liked by his colleagues and the many farmers whom he met in the course of his duties.

A list of appointments and resignations is given in the Summary Report on Advisory Work.

Buildings.

The congested state of the accommodation at the Berkeley Square Centre becomes more serious every year. At the end of the year under review the number of people regularly at work in the buildings was 59, including those members of staff whose work is mainly outside Bristol, but who also require accommodation when they return to the Centre. Apart from congestion in the laboratories, the cloakroom accommodation is now hopelessly inadequate and the lack of a rest-room or staff-room is frequently felt. It is to be hoped that this question can be given serious consideration at the earliest possible moment in view of its undoubted urgency and its effect on the efficiency of the work.

Proposals for the extension of the Evesham Field Laboratory have been considered by the Ministry of Agriculture and with the help of the Ministry of Works (Birmingham) attempts are being made to find a suitable site in Evesham

for a new building. This building will be planned to accommodate a mycologist and an entomologist, together with a technical assistant who would also help with clerical work.

LONG ASHTON RESEARCH STATION.

Staff.

The administrative arrangements outlined in the previous report were continued in 1944 and have worked efficiently.

No changes have occurred in the senior staff and changes in the scientific assistant staff have also been few.

Mr. J. A. H. Tolhurst, B.Sc., was appointed on 17th March, 1944, as Chemical Assistant under the Agricultural Research Council special grant for mineral deficiencies investigations.

Mr. C. H. Hoddell was appointed on 25th January, 1944, as Spraying Instructor under a scheme of the Ministry of Agriculture and Fisheries to provide instruction to County Spraying Teams.

Miss J. Bryan, B.Sc., was appointed on 3rd October, 1944, as Chemical Assistant in Fruit Products to replace Mrs. J. Steedman, B.Sc., who resigned on 31st July, 1944.

Mr. N. G. Morgan, B.Sc., Spraying Officer, Gloucestershire W.A.E.C., was seconded to the Station from September 1st to October 31st, under a special grant from the Ministry of Agriculture and Fisheries, to assist Dr. Kearns in the construction of an Atomiser for use on field crops.

During the year five technical assistants were appointed to assist in laboratory work, in Pomology, Cider, Fruit and Vegetable Preservation, Entomology and Advisory Mycology. These appointments have proved of very great help in the Sections concerned.

Sanction was also obtained from the Agricultural Research Council for a Scientific Assistant for Field Survey work on Mineral Deficiencies, but the appointment has been postponed until Spring, 1945. An appointment of similar grade, sanctioned for Plant Pathology, has had to be postponed pending the provision of suitable accommodation for the work contemplated.

Mr. A. Wilkins, technical assistant in Entomology, met with a serious road accident whilst cycling on December 20th, 1944, which resulted in a fractured femur. Fortunately he has made a good recovery and is expected to resume work during Spring, 1945. The absence of Mr. Wilkins has been a great handicap to Dr. Kearns, both in his entomological investigations and his work on various machines, as Mr. Wilkins is specially skilled in both branches of work.

Buildings and Land.

The serious need for additional laboratory and office accommodation was stressed in the previous report. During 1944 the laboratory situation was considered so acute that representations were made to the Ministry of Agriculture to provide a temporary building to meet the most urgent needs. The Ministry, after consideration of the proposals, have asked the Committee to submit plans and estimates, and arrangements have been made for the Ministry of Works to assist in this task. The proposals comprise the provision of rooms to accommodate the Advisory Entomologist and his staff and some of the pomological recorders, additional accommodation for the research entomologist, and special rooms for insect breeding and rearing and testing of sprays. The additions will enable certain lines of work now in abeyance, due to lack of facilities, to be proceeded with, and will make room in the main building

for two or three workers who at present cannot be properly accommodated. Unfortunately the main building will remain in a congested state, and an urgent building problem must be faced in the immediate post-war period if the development of the work is not to be seriously impaired.

During the year, after consultation with the Ministry of Agriculture, the museum adjoining the library was converted into a canteen. Although the museum could be ill-spared for this purpose the advantages of having the canteen outweighed all other considerations and the sacrifice was inevitable. The venture has been an unqualified success, the number of lunches served daily since the opening having varied between 40 and 60. The arrangements are greatly appreciated by both the laboratory and plantations staffs, and it seems clear that more permanent arrangements should be made after the war.

Working conditions in the cider house at present are not satisfactory and proposals are under consideration to improve matters. The difficulties arise from the fact that the work has outgrown the original accommodation and re-planning of the premises, involving some new buildings and structural alterations to the existing buildings, will be necessary to bring the accommodation up-to-date. Most of the additions and changes contemplated will not be possible until the post-war period.

During the year it was necessary to fit a new brine tank into the experimental cold store, the old tank having become unserviceable from corrosion. The large pomace drier was sold to a commercial firm, as it had ceased to serve the purpose for which it was installed.

Dr. Kearns has continued to supervise the work in the Station repair shops which again have been of great value in carrying out maintenance work on property, and in servicing machinery and vehicles and repairing implements.

In addition the workshop facilities have enabled Dr. Kearns to undertake the designing and building of a special atomising machine for the spraying of field crops. The thanks of the Station are due to Dr. Kearns for his continued help in the maintenance of property, machinery and implements.

Mr. J. H. Butler has continued his tenancy of the outlying portions of the Station farm.

The work in the plantations has continued as in previous years and there have been no major changes in cropping policy. Fruit and vegetable crops were satisfactory and yielded good financial returns.

Approximately 420,000 seedling apple stocks were raised on behalf of the Ministry of Agriculture, and arrangements are in hand to raise further supplies of seedling apple, pear, plum and cherry stocks under the Ministry's Scheme in 1945. The stocks are intended to meet in part the large deficit which has resulted from the cessation of nursery work during the war. The Station is also co-operating with the Ministry in raising black currants and loganberries to meet the post-war shortage, and in this connection stocks of the Long Ashton black currant seedlings Mendip Cross and Cotswold Cross are being increased to the utmost extent of the available material.

At the request of the Agricultural Research Council an experiment has been commenced on black currants to test the manurial value of sewage sludge, town refuse materials and composts made from these materials. The experiments should be of interest not only to fruit growers but also to Local Authorities anxious to find outlets for these waste materials.

Research on willows has been in abeyance since the retirement of Mr. Hutchinson in 1939, since when the willow beds used in the work have been

maintained at a low level of cultivation pending a decision as to whether the work is to be continued. A small grant has now been made by the Agricultural Research Council to enable the beds to be partly replanted and to provide for extra cultivation.

As the 1944 crop of cider fruit was a large one, a special effort was made to produce an unusually large quantity of cider. The programme was made possible by the help of Italian prisoners of war and, in spite of unfavourable weather conditions during and after harvesting, the work was accomplished in a fairly satisfactory way.

Working conditions in the plantations during the year were very difficult, especially in the autumn, which was notable for rain and gales, and the management and labour staff are to congratulated on the production and safe harvesting of heavy crops under most trying conditions.

Research Activities.

The main items of research in 1944 have been in continuation of those reported in 1943. The studies on mineral deficiencies of plants were continued under the scheme of the Agricultural Research Council, and arrangements were made for the publication of a Supplement to "The Colour Atlas and Guide," published in 1943. Surveys of deficiencies were made in Somerset and in several districts in the north of England. Methods of controlling magnesium deficiency in glasshouse tomatoes by means of magnesium sulphate, used either as a soil dressing or as a spray, have been worked out. This deficiency had become serious during the past few years.

Land classification surveys were commenced in Gloucestershire, Somerset and Wiltshire for the University of Bristol Reconstruction Research Group, and it is hoped to complete the work by the summer of 1945.

Experiments on composting were begun and field tests on the value of sewage sludge and sewage sludge/straw composts for market garden crops were carried out in conjunction with members of the staff of Rothamsted Experimental Station.

A programme of work under the special grant of the Agricultural Research Council for Hop Diseases Investigations in the West Midlands was carried out, special attention being given to determining the incidence and importance of various diseases in the hop growing areas.

Interesting experiments have been carried out on the use of growth promoting substances in relation to fruit setting, parthenocarpic development of fruits and pre-harvest drop of apples. The results on pre-harvest drop are immediately applicable to practice, and a possible practical application of the results on parthenocarpic development of tomatoes is to be tested in 1945.

Two virus diseases in apples and one affecting pears have been shown to occur in English orchards, and in collaboration with workers at East Malling and at the John Innes Horticultural Institution, investigations have been commenced on some abnormal characters in the apple variety Lord Lambourne which threaten this very promising commercial variety.

The Station pathologists have continued their studies on new fungicides and insecticides, and in particular have been closely associated with investigations on the new insecticide D.D.T. Dr. Martin has also served on several committees dealing with the standardisation of commercial spray materials.

Dr. Kearns has continued his work on spraying machinery and eqiupment on behalf of the Ministry of Agriculture. He has received a special grant from the Ministry to enable him to design and build a machine for the atomisa-

tion of sprays such as B.O.V. sulphuric acid. Substantial progress has been made with the problem.

In the Fruit and Vegetable Products Section, attention has been given to the important problem of the blackening of cooked potatoes and to the effects of cultural and other conditions on the vitamin C content of tomatoes. The potato investigations have shown that on certain soils blackening cannot be overcome by manuring. The choice of suitable varieties is a much more hopeful method of attacking the problem.

A beginning has been made with a collection of colour photographs of the better known cider apples. Approximately 100 varieties were photographed in 1944, and it is hoped to extend the collection as opportunity occurs. Professor Barker would be glad to hear from growers in future years who have numbers of varieties in fruit so that he may have an opportunity of obtaining samples of sorts to add to the collection.

Miss Crang has published a book, " Preserves for all Occasions," as a Penguin Book. Studies on vitamins in fresh and preserved fruits have been continued in an assay of riboflavin.

Annual Field Day. Following war-time policy the Annual Tasting Day was not held. An Open Day for Members of the Institute was, however, held on the occasion of the Annual Meeting of the National Fruit and Cider Institute on 5th July, 1944.

Visitors. The numbers of visitors and organised parties have shown sharp increases during the year. The parties have been representative of a wide variety of organisations. The list of parties is as follows :—

Advisory Chemists' Conference (Mid-Western Section).
Association of Scientific Workers.
Bristol Growers.
Bristol Group Youth Hostels Association.
B.B.C. Foreign Broadcasters.
Bedminster Tabernacle.
Bentley School Science Society, Calne, Wilts.
Bristol University Chemical Society.
Bristol University Permanent Staff Senior Training Corps.
Bristol University Youth Leader Training Group.
Buckinghamshire W.A.E.C.
Canadian Forces.
Clevedon Senior School Young Farmers' Club.
Colston Girls' School (2).
Fishponds Diocesan Training College.
Gloucestershire W.A.E.C.
Ham Green Training Centre for Boys.
Institute of Handicraft Teachers.
Merchant Venturers Pharmacy Students' Association.
Ministry of Food (Food Advice Students).
N.A.G.C. Course in Youth Leadership.
North Hammersmith Senior School.
North Somerset Young Farmers' Club.
Pershore and Worcester Young Farmers' Club.
Plant Protection Ltd.
Reading University Horticultural Students.
Robinson's Waxed Paper Co., Ltd. (2)
Staple Hill Senior School (2).
Usk Young Farmers' Club.
Waterperry Horticultural Training College.
Wiltshire W.A.E.C. (2).
Women's Farm and Garden Association.
Worcestershire W.A.E.C.
Soldiers and A.T.S. of Royal Artillery, Anti-Aircraft and Searchlight Batteries (6).

Shows, Demonstrations, etc. The exhibits provided during the year have, in the majority of cases, been in collaboration with County War Agricultural Executive Committees and have been in connection with " Dig for Victory " and " Produce " Shows. The following is a list of places to which exhibits have been sent :—

Badsey, Worcs.
Bath Horticultural Show.
Cheltenham, Glos.
Frenchay, Glos.
Hereford
Kingswood Produce Show.
Little Wishford, Wilts.
Offenham, Worcs.
Willsbridge, Glos.

Demonstrations were given by members of staff at the following places :—

Orchard Renovation (including cleaning, blasting, headworking and spraying) ..	Bledisloe Orchards, Glos.
do.	Kent's Green, Tibberton, Glos.
do.	Arlingham, Glos.
do.	Tewkesbury, Glos.
do.	Dumbleton, Glos.
Wireworm Control	Young Farmers' Club, Orleton, Herefordshire
do.	do. , Kingsland, do.
do.	do. , Ledbury, do.
do.	Market Demonstration Bromyard, do.
do.	do. , Leominster, do.
Frit Fly and its Control	do. , Ewyas Harold, do.
do.	do. , Ross, do.
do.	do. , Hereford, do.
do.	do. , Bromyard, do.
do.	do. , Peterchurch, do.
Flea Beetle Control	Harnhill, Glos.
do.	Worcestershire.
do.	Somerset Farm Institute, Cannington, Som.
Insects and the Farm	Young Farmers' Club, Chippenham, Wilts.
Insect Pests of Farm Crops } ..	County Rally, Dauntsey's School, Wilts.
Dusting for Flea Beetle Control } ..	

Research Students and Voluntary Workers. There have been no research students during the year, but Mr. Gerald W. H. McCarthy has spent a period at the Station taking a course of practical instruction in the art of cider making.

Scholars from Clifton High School and the Colston Girls' School again rendered valuable assistance in the fruit plantations during their summer vacation. Parties of Girl Guides from West Bristol also gave similar help, and to all of these the Station wishes to record its thanks for their continued voluntary service.

Mr. H. E. Beviss has again given valuable voluntary help throughout the year in the plantations recording work, and to him the Station is particularly grateful.

Acknowledgments. It is gratifying to be able to report the continued help and co-operation of numerous growers, industrial firms and other organisations and of many persons during the year. The methods by which assistance and collaboration have been effected have been varied, including financial support, personal collaboration in experiments and surveys, provision of facilities for field trials, factory tests and operations, and personal advice and experience. All forms of help given have contributed to the success achieved and sincere thanks are due to all who have so willingly co-operated.

Thanks are due to the scientific staff who have continued to work at very high pressure, often under unfavourable conditions. In addition to their work many have undertaken special duties to forward the work of the Station. In this connection the assistance of Dr. Kearns, Miss Crang and Miss Sturdy in the establishment and running of the canteen, and of Mr. Marsh in undertaking editorial work call for special mention.

All other grades of staff have co-operated loyally and a special word of thanks is due to the cider house and plantation staffs, who not only implemented large production programmes but also rendered invaluable assistance with the experimental work.

INTENSIVE SYSTEMS OF APPLE PRODUCTION WITH PARTICULAR REFERENCE TO DWARF PYRAMIDS.

By E. W. HOBBIS.

Introduction.

Of all branches of fruit culture, that of apple growing seems to make widest appeal, especially amongst those retiring from other walks in life and entering the fruit production industry at a comparatively late age. The planting of fruit on a long term policy rarely appeals to people in these circumstances. A quick return on capital expended is an unfailing attraction, so a quest begins for a short term policy which will provide early returns in crop and income from comparatively small areas of land.

Various intensive systems of apple growing have been exploited during the past ten years. Lees (1), writing in the *Gardeners' Chronicle* for May 1928, described a system whereby apple trees on Type II rootstocks, planted at approximately 2,400 to the acre, were trained as dwarf pyramids to produce early and heavy yields per acre. A trial plot, demonstrating Lees' system, was laid down at Cannington, Somerset, and reported on in 1935 (2). Gaut (3) and Gaut and Hobbis (4), writing in the *Worcestershire Agricultural Chronicle* in November 1932 and February 1937, described experiments in budding rootstocks *in situ* in close planted rows (11,600 stocks per acre) and building upright cordon trees to crop where propagated. The Ministry of Agriculture and Fisheries Bulletin No. 49, titled " Intensive Systems of Apple Production," includes a survey of methods in vogue at the time the bulletin was compiled (1932).

With the coming of peace many people released from the Forces will be looking to the land for an occupation, some as a completely new venture in life. Fruit growing will undoubtedly receive an influx of newcomers, and it is to those who contemplate starting apple growing on any intensive method that this report is particularly addressed.

Plantations of upright or oblique cordons, dwarf bush plantations on Type IX rootstock and dwarf pyramid trees are amongst methods already employed. It is proposed in this report to review the performance of a commercial, dwarf pyramid plantation which has been under the writer's notice since it was planted. It must be realized that the owner commenced operations with a very wide knowledge of commercial fruit growing both in this country and in New Zealand, and that the venture therefore cannot be compared with that of a newcomer to the industry. The plantation under review is situated in Wiltshire and planting commenced in 1933–34.

Site and Soil. The plantation is on a fairly level " tongue " of land approximately 380 ft. above sea level which is bounded on three sides by very steep slopes, the valley bottoms of which are known " frost pockets."

The soil is a fertile, easy working light loam, varying from 9—18 in. in depth and overlying Upper Greensand ; water drainage is very free and on the shallow measures drought effects have been noted during the past three summers. The land was down to pasture when taken over.

Planting History.

Planting commenced in the winter of 1933–34. Planting distance throughout was 6 x 3 ft., which, when roadways are taken into account, allowed 2,300

trees per acre. Varieties chosen were Cox's Orange Pippin, Ellison's Orange, Worcester Pearmain and Laxton's Superb, all on Malling Type II rootstock. In addition, one tree of the culinary variety Early Victoria (Emneth) was planted to every three Cox to act as pollinator. This variety was worked on Crab stock. The inclusion of a pollinator in the proportion of one to three of the main variety reduced the actual number of Cox trees per acre by 25%, a high premium to pay to provide for adequate cross-pollination. In pre-war seasons Early Victoria was a low-priced apple, often difficult to sell, and each ¾ acre actually devoted to Cox had therefore to carry, to a large extent, the cost of management of the pollinator.

Further plantings took place in 1935–36 of trees all budded and raised in the grower's own nursery and set out as maidens, as were all other trees in this plantation.

For the purposes of this report varieties Cox, Ellison and Superb only will be dealt with. Worcester has not reacted favourably to the system and no records have been kept of this variety.

These further plantings have brought the number of trees of each of these varieties to Cox 9,000, Ellison 1,050, Superb 2,300.

Pruning. All trees were planted as maidens, which were then cut back to about 2 ft. 6 in. The aim since has been to grow a tree with a central stem from which radiate well-placed, wide-angled, lateral branches, which in turn were furnished with spur systems and used for the annual production of new wood.

At no time has a uniform system of pruning been possible. Each tree has had to be pruned on its merits. In general leader growth has been cut hard, whilst lateral shoots have been lightly pruned or left untouched. Flower buds have formed along the length of these laterals in the following year and pruning has then been designed to reduce the number of flower buds by varying degrees of cutting back.

Summer pruning was a regular routine until the war made its continuation impossible. Summer pruning was practised in order to restrict growth, all lateral shoots on reaching 1 foot in length being cut back to 4 buds. It is interesting to note that tree growth response to winter pruning and cropping capacity have been improved by the elimination of this summer cutting. During the early years many laterals, of Superb in particular, were left intact and tied down horizontally to slow down growth and encourage flower bud formation.

The general aim throughout has been to keep a balance between shoot growth and flower bud formation, and this has been accomplished mainly by the judicious cutting out of some wood each year to encourage new shoot growth and leaving intact or nearly so a reasonable proportion of new shoots. Pruning therefore has entailed numerous small cuts and even in later years when lateral branches have been in a sense " de-horned " to stimulate new shoot growth, no cuts have proved too big for the secateurs. The cost of pruning can be judged from the fact that fully-formed trees can be pruned at the rate of approximately 18 per hour.

Tree extension upwards has been comparatively slow, and now in their eleventh year few trees of the three particular varieties are above 6 ft. high. Laterally, however, the trees have filled out comparatively quickly and the mature plantation now consists of solid lines or " hedges " of trees. The close planting has resulted, inevitably, in a crowding of the lower branches of neighbouring trees, and this crowding has tended to progress upwards in

succeeding years. The checking of this overcrowding has been one of the most speculative of the winter pruning operations, and in spite of spur thinning and the removal of grossly overcrowded wood it has been extremely difficult to encourage young growth in the lower parts of the trees during the last few years. Spur systems seem to age quicker under these conditions than on wide planted trees, and once new extension growth ceases the cropping capacity of the tree quickly falls and acute biennial bearing sets in.

Cultivations. In the early years clean arable cultivation was maintained by a small motor-driven cultivator and hand work around the trees. Over-vigorous growth was checked and early fruiting encouraged by allowing the land to fall down to a " grass-weed " cover from July onwards in the first instance. Later management has entailed the leaving down for one or more seasons, or the breaking up of this " cover " as growth requirements have demanded, *e.g.* breaking-up would be done in March after a season of insufficient growth.

The mowing of the grass and weed was a comparatively easy matter in the early years and was done by scythe and hook. As the trees spread this operation became difficult and the work was done by Allen motor-scythe with complete satisfaction.

The breaking-up of the " cover," however, presented a difficult problem. The amount of mown material proved too bulky to be dealt with by ridged tined cultivator. For a time the mulch had to be raked up and stacked on the roadways to be composted and later put back after arable cultivations had been renewed. This problem, however, was solved by the introduction of a Rotehoe, a cultivator working on the rotary principle, and the ground can now be broken up at will without any interference from an accumulated grass mat.

Manuring. Heavy annual applications of potash were given prior to war-time restrictions on supply and averaged 2—3 cwt. per acre of sulphate of potash per year from 1934 to 1940 inclusive. Since 1941 potash dressings have been very small in amount and flax-ash (shivings) has been relied upon mainly for a source of supply. It would seem, however, that the heavy dressings over a period of 8 years have served the plantation to good purpose as potash status has been generally satisfactory.

Nitrogen applications together with clean cultivation or grassing down have been held as a trump card in the hands of the grower. These two factors in management have been interlinked very closely and together with a certain flexibility in pruning have been the master key to achieving successful conditions of vigour and fruiting. Nitrogen has usually been applied in the form of nitro-chalk, which has also promoted the breaking down of the annual accumulation of grass mowings beneath the trees.

In the early years nitrogenous fertilizers were not required, but heavy dressings have accompanied the letting down to grass and weed of any part of the plantation. Here again flexibility in management has been vitally necessary to keep the trees growing just strongly enough to furnish new wood annually and yet provide heavy crops of highly coloured fruit. On the oldest blocks of trees, hoof and horn meal at 3 cwt. per acre has been used in conjunction with 2–4 cwt. sulphate of ammonia.

The decision as to when to grass down was dictated by the trees themselves. Conversely just when to break up the grass and weed cover was indicated by a marked diminution in new wood production and the over-production of blossom buds. The breaking up of the grass cover has followed an application of up to 5 cwt. nitro-chalk per acre.

It is in this connection that the use of efficient small powered tools will be readily appreciated, and it can be stated that the plantation in question could never have been maintained in a first-class condition without the use of such tools as the Allen scythe and the Rotehoe cultivator.

Phosphate applications have not been included annually in the manuring programme, 3–4 cwt. per acre of superphosphate being considered ample every few years.

Pest and Disease Control. The owner of the plantation under review commenced planting with a full awareness of the problems of pest and disease control likely to affect the success of the venture.

Planting, therefore, was done from the start with the certain knowledge that thorough and frequent spraying would be demanded within a very few years. To this end roadways and length of row were so planned to make every block of trees easily accessible and underground mains were laid along these roadways in 1937, *i.e.* 3 years after planting the first trees. This policy, seemingly to some a piece of extravagance at the time, has justified itself amply.

A central, electrically-driven pump delivers mixed wash to stand pipes which are provided every 11 rows of trees (6 ft. apart), *i.e.* every 66 ft., and by using a 120 ft. hose and a short, double-nozzle lance with a pressure of 300 lbs. per sq. in. it has been possible to spray the trees efficiently and quickly. For example, the time taken for two people to mix wash and spray the 18,000 trees in the plantation with a pre-blossom lime sulphur wash now averages 4–5 full days, post-blossom application taking 6 days.

The basic spray programme has been winter washing followed by two pre-blossom and two post-blossom lime sulphur applications. The latter have sometimes been followed with 4 or 5 applications of dust, especially on Superb, which has proved very prone to Scab infection on this farm.

Pollination. In conjunction with the provision of pollinators throughout the Cox plantations, as referred to earlier, upwards of 20 stocks of bees have been kept in the plantation during recent years and the owner is convinced of their value in helping to set full crops. Bees kept within a plantation in this way can take advantage of comparatively short spells of suitable flying weather in an otherwise difficult blossoming period, and having large amounts of blossom of one kind in close proximity to their hives encourages them to concentrate on the one type of bloom only.

Crop Records. The underlying idea of a close-planted dwarf pyramid plantation is to provide profitable returns within a very few years of planting.

The following table sets out the crop returns per tree and per acre of the three varieties Cox's Orange Pippin, Laxton's Superb and Ellison's Orange over a period of years. The figures have been carefully collected and reflect faithfully the performance of the varieties in this particular plantation. It is important to remember in the case of Cox that one quarter of every planted acre is occupied by the pollinator variety so that only 1,725 Cox trees actually stand on any one acre, the remaining 575 trees being Early Victoria.

As 2,300 trees are planted per acre it is useful for practical purposes to estimate that a crop of 1 lb. per tree is equivalent to 1 ton of fruit per acre, *i.e.* 56 bushels per acre. This assumption has been noted in the table appended. Crops in 1938 and 1944 were much reduced by sharp frosts in May.

Discussion.

The plantation under review in this report is now in its eleventh year. It has been managed throughout with considerable skill, and pruning has been

DWARF PYRAMIDS. CROP YIELDS (Per Tree; Per Acre).

Planted at 2,300 trees per acre.

N.B.—The Superb and Ellison's blocks are "straight" plantings, but Cox's are pollinated with Early Victoria (1 in 4) and so the Computed Acreage Yields in bushels for this variety are calculated on the actual plant at 1,725 trees per acre.

Year.	Cox's Orange.				Laxton's Superb.				Ellison's Orange.			
	Number of trees.	Age from Planting.	Average Lbs./ Tree.*	Crop Wt. Bushels/ Acre.	Number of trees.	Age from Planting.	Average Lbs./ Tree.*	Crop Wt. Bushels/ Acre.	Number of trees.	Age from Planting.	Average Lbs./ Tree.*	Crop Wt. Bushels Acre.
1934	5,000	1										
1935	,,	2										
1936	9,000	3–1	3·0	130	500	1			900	1		
1937	,,	4–2	3·0	130	2,300	2–1	1·5	86	950	2–1	0·75	43
1938	,,	5–3	0·5	22	,,	3–2	1·0	58	,,	3–2	3·25	187
1939	,,	6–4	7·0	302	,,	4–3	4·5	259	,,	4–3	8·0	460
1940	,,	7–5	2·0	86	,,	5–4	1·0	58	,,	5–4	4·25	245
1941	,,	8–6	5·0	216	,,	6–5	7·25	417	,,	6–5	10·25	590
1942	,,	9–7	4·5	194	,,	7–6	1·0	58	1,050	7–6–1	7·0	403
1943	,,	10–8	8·0	345	,,	8–7	9·75	561	,,	8–7–2	10·5	604
1944	,,	11–9	0·75	32	,,	9–8	0·3	17	,,	9–8–3	3·0	172

* Lb. per tree = Tons per acre (approx.).

the personal responsibility of the owner, who has carried out practically all machine cultivations. An extra hand has been employed for spraying operations since 1939 and woman labour has been employed during the picking season. All grading and packing has been undertaken by the grower and his wife, without outside help except for various odd, unskilled jobs.

Crop records show what are possibly the maximum yields to be expected from this type of plantation, and it is particularly interesting to note that Ellison's Orange has proved the heaviest cropping variety, with an average of 6 lb. of fruit per tree over a period of 8 years from the second year after planting.

Cox's Orange Pippin has cropped very consistently, but Laxton's Superb has been very erratic, a biennial tendency in bearing being closely shown. The vigorous growth of this variety has accentuated the over-production of new wood in " off " years, and it has been impossible to keep the trees within small confines. One block is now being progressively thinned, $\frac{7}{8}$ of the trees being removed, with the idea of allowing the remaining trees a space 12 x 12ft. in which to expand and make bigger pyramid trees.

The plantation probably is now at its peak of production, and trees included in the first two plantings are becoming overcrowded with consequent loss of lower branches. A de-horning of some of these lower branches to induce new shoots has been partially successful, but overcrowding is still apparent.

The Early Victoria pyramids worked on Crab and interplanted with Cox's Orange Pippin trees, as pollinators have no doubt filled this rôle very well, but their rapid increase in size, out of all proportion to the Cox trees, has had its disadvantages. In one overcrowded block a proportion of the Early Victoria trees has been frame-worked to Cox or Superb with a view to the future establishment of large trees at a much wider planting distance.

The question, how long can this type of plantation remain profitable, has not as yet been answered in this instance. It does seem, however, that peak yields have been reached for the present planting distance.

Early yields and good returns per acre have been obtained, but what is the future of the plantation ? Should the system be looked upon as a rotational one ? Attractive financial results under present conditions are no criterion of what may happen in more normal times. The dwarf pyramids under review have come into their best just at a time when high prices have been obtained for all home-grown fruits, and the returns have been enhanced further by the fact that Cox, Superb and Ellison have constituted the highest priced group.

Can trees planted so closely and treated so intensively provide any substantial contribution to the apple growing industry of the country ?

The position of tree supply for some years to come is likely to be difficult. Any planting under this system of trees on nondescript rootstocks would lead to disaster. The number of trees required per acre, say 2,300, would reduce drastically the number of trees likely to be available for the grower of fruit on the more extensive system. A batch of 2,300 Cox trees, for example, would suffice to plant up to 17 acres of bush plantation. It is interesting to note also that the price of maiden trees pre-war was between £5 and £7 per 100. To-day's price is in the region of £20—£30 per 100 or a planting cost in trees alone of at least £460 per acre, if this intensive system is adopted.

Conclusion.

The method of apple growing reviewed has been shown capable of success as a short term policy in the hands of a very knowledgable grower. He has

Section of Dwarf Pyramid Plantation. Variety Cox's Orange Pippin, 9 years after Planting.

carried out personally almost all of the detailed operations involved and here, very largely, is the reason for success.

Any intending planter would do well to consider carefully the foregoing before committing himself to a system of growing, which in some aspects demands more detailed attention and knowledge than does a wide planted bush plantation. It is certainly no easy road for the beginner to embark upon. The method needs much capital per acre and demands much work and close application. It gives quick returns, but over a comparatively short period.

Whilst the older grower will always have a special interest in such methods, the younger man would probably find more scope and a long period of profit in trees widely spaced and capable of attaining maximum developnemt.

Acknowledgment.

The writer is indebted to J. Partridge, Esq., for the facilities afforded at all times in connection with the recording of data and for the provision of accurate figures of yield.

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THE PERFORMANCE OF CERTAIN VARIETIES OF PEAR ON VARIOUS ROOTSTOCKS AT LONG ASHTON.

PROGRESS REPORT I.

By E. W. HOBBIS & E. CATLOW.

Introduction.

It is often considered that the climate of the West of England is neither dry enough nor the summers warm enough for the growing of pears to perfection. Pears, however, have long been grown in the West, in early days largely for perry making, but for some time past high quality dessert pears have been grown in commercial plantations. This development has followed largely on the introduction of the variety Conference, which is highly resistant to scab attack, and also to advances made in the control of scab.

The present progress report deals with the performance of a number of varieties of pear which were planted at the Research Station in the winter 1934—1935 at 15 feet x 12 feet (242 per acre). During the 10 years under review soft fruits have been grown beneath the trees. These are due to be removed after cropping in 1945, after which the pears will enter a new phase in management. The present time therefore seems opportune for the presentation of a report on the early stage of the experiments.

Both maidens and 2-year-old trees were planted. Varieties were worked in varying number on Quince rootstocks, on two layered seedling rootstocks

from East Malling Research Station and a third layered seedling rootstock from a Midlands fruit farm.

The variety Conference was represented in greatest number. Trees were worked on Quince A, B, C, and G and on the three layered seedling rootstocks. It is proposed therefore to refer to the performance of all varieties and to draw special attention to the variety Conference which is represented in greatest number and on all the rootstocks used.

Soil and Soil Management.

The soil is derived from fine sandy drift material overlying Keuper Marl. The sandy surface soil which varies from 9 inches to 14 inches in depth overlies a somewhat impervious subsoil derived from the marl. Extensive drainage by land drains, overlaid with clinker, has been necessary to prevent water-logging in winter.

Prior to being planted to pears the plot was used as a tree nursery and a cabbage crop was taken before planting the pears.

The 15 x 12 foot plant was undercropped with red currants which were grubbed in 1937 and replaced by black currants. These soft fruits were planted E.—W. along the tree rows only, and except in the early years, mechanical cultivations have been in the one direction only, the tree row being cultivated by hand.

Autumn weed has been allowed to remain until winter pruning and spraying have been completed. The tree rows have then been hoed out and the alley ways shallow-ploughed. Spring and summer cultivation has been by discs and spring-tined cultivator.

Varieties Planted.

The plot consisted originally of 537 trees. This total was made up of trees in varying numbers of the following varieties :—

Conference, William's Bon Chretien, Beurre Bedford, Doyenne du Comice, Beurre Hardy, Bristol Cross, Duroudeau, Fertility, Dr. Jules Guyot and Laxton's Superb.

Rootstocks.

Seven rootstocks were used, four Quince and three layered seedlings, viz. Quince A, B, C and G, and layered seedlings B1 and D3 from East Malling, and the third from a Midlands fruit farm and for the purposes of this report called " Hiller."

Manuring.

In the year of planting, trees and bushes were mulched with F.Y.M., and from then until 1941 the plot received an annual dressing of inorganic N.P.K. fertiliser at the rate of 2:3:2 cwts. per acre. Since 1942 the phosphate dressing has been reduced to 2 cwt. and the potash (now muriate) to $\frac{1}{2}$ cwt. per acre. In addition to these fertilisers the black currants have had an annual dressing of 2 cwt. nitro chalk in April.

Pruning.

The trees were intended originally to be of " delayed open centre " type, but in the winter of 1936–37 the centres were removed and this has resulted in a bush tree having its main limbs arising from a considerable length of stem.

Leaders have been shortened annually by about $\frac{1}{3}$ to $\frac{1}{2}$ but procedure regarding this point has not been standardised.

Laterals have been left intact if up to 5—7 inches long, provided they were not overcrowded. Over-vigorous laterals have been cut out, and those of

medium vigour but over-long have been shortened to 3—5 buds. A more orthodox pear pruning method would have entailed a harder winter pruning but under Long Ashton conditions of growth and climate the lighter pruning seems justified.

Pest and Disease Control.

A tar oil at 5% was regularly applied up to the winter of 1942, since when winter washing has consisted of D.N.C. Petroleum at 5% concentration.

The Spring programme has included two pre-blossom applications of lime-sulphur at 3% and two post-blossom applications at 1%. Scab control has been excellent both on the fruit and on new wood, and canker has been almost entirely absent. The lime sulphur applications have caused no leaf damage, except to the variety Comice, where it has not been serious.

Records.

Up to the autumn of 1944 records taken comprised girth measurements at one foot above union of stock and scion, blossom categories, period of blossoming, fruit numbers and crop weights.

Recording of tree spread and height, in abeyance from 1939 to 1943, was resumed in the winter of 1944, when it was possible to record spreads and heights in addition to girths.

Notes were made in the autumn of 1944 on tree size and habit, appearance of foliage and fruiting habit of every tree. These notes have been summarised and are incorporated in Table II. Scion rooting was also confirmed in some cases.

General Observations—All Varieties.

Table I sets out the varieties and rootstocks used and the number of trees originally planted on each of these rootstocks. In brackets, after each number and in italic type, is shown the number of casualties which have occurred to date from the time of planting in 1934.

Two facts stand out (*a*) the total loss (except one) of all trees of the varieties Conference, Beurre Bedford and Doyenne du Comice when worked on to Quince G, and (*b*) the loss of 52 trees of William's Bon Chretien on Quince A, B and C out of a total of 81 planted originally, whilst no tree of this variety has been lost on layered seedling B1 or D3.

Except for a few scion rooted trees (recorded as casualties) losses of trees have been due directly or indirectly to Autumn gales, which annually sweep over the plot whilst leaf is still on the trees.

Tree staking has been a difficult problem and losses have usually occurred when gales have followed heavy rains. These have saturated the soil and caused trees to blow over complete with stakes.

With William's Bon Chretien, however, every casualty has been occasioned by a clean break at the union of stock and scion. This occurrence confirms the fact already known that the variety Williams is incompatible with all the Quince rootstocks.

It has been noted, too, that several Bristol Cross trees on Quince have broken at the union, possibly showing some degree of incompatibility.

Scion Rooting.

Once a tree becomes established on its own roots the fact ultimately becomes apparent to the eye by reason of a change in growth habit of the tree, provided it has been worked on one or other of the Quince rootstocks. It is possible, however, that trees in the early stages of scion rooting show no change

TABLE I.

ORIGINAL PLANTING NUMBERS 1934, AND NUMBER OF CASUALTIES 1934—1944.
(Casualties denoted by figures in brackets).

Stock :—	Quince.				Pear.			
	A	B	C	G	Hiller	B1	D3	
Variety.								Totals.
Conference	31 (*1*)	28 (*2*)	75 (*5*)	17 (*17*)	25 (*1*)	6	6	188 (*26*)
Williams	18 (*12*)	25 (*17*)	26 (*23*)			6	6	81 (*52*)
B. Bedford	22 (*1*)	6	14 (*3*)	8 (*7*)				50 (*11*)
Comice	19 (*2*)		25 (*2*)	5 (*5*)		6	6	61 (*9*)
B. Hardy	12		12 (*1*)			6	6	36 (*1*)
Bristol X	7 (*2*)	14 (*4*)	13 (*6*)					34 (*12*)
Durondeau	12		13 (*1*)					25 (*1*)
Fertility	13 (*2*)	12 (*5*)						25 (*7*)
Guyot	12 (*4*)		13 (*4*)					25 (*8*)
Superb	6	6						12
Totals	152 (*24*)	91 (*28*)	191 (*45*)	30 (*29*)	25 (*1*)	24	24	537 (*127*)

TABLE II.

GROWTH AND VIGOUR RECORDS : OCTOBER 1944.

Variety.	Rootstock.	Age at planting (yr.)	No. of trees.	Height (ft.)	Spread (ft.)	Girth (in.)	Observations 12–10–44.
Conference	Quince A	1	25	10·9	7·3	10·8	Medium vigour, upright, well spurred
,,	,,	2	5	11·2	8·1	10·5	
,,	Quince B	1	18	9·4	5·9	7·5	Fair vigour freely spurred
,,	,,	2	9	9·4	5·9	8·6	
,,	Quince C	1	52	8·8	12·4	8·1	Fair vigour, slightly defoliated, well spurred
,,	,,	2	19	7·8	10·8	6·9	
,,	Pear B1	1	6	14·0	10·1	14·2	Vigorous, upright, sparsely spurred
,,	,, D3	1	6	14·7	9·4	14·6	
,,	,, Hiller	1	6	11·8	7·8	11·4	Medium vigour, well spurred
Williams	Quince A	1	6	10·4	7·3	8·1	Medium vigour, prolific
,,	Quince B	1	6	9·8	6·3	7·9	do.
,,	,,	2	2	11·2	7·3	8·1	do.

TABLE II—*continued.*

Variety.	Rootstock.	Age at planting. (yr.)	No. of trees.	Height (ft.)	Spread (ft.)	Girth (in.)	Observations. 12–10–44.
Williams	Quince C	1	1	4·6	1·7	2·8	Fair vigour, well spurred, scion rooted
,,	,,	2	2	8·9	4·3	5·6	
,,	Pear B1	1	6	15·2	9·8	10·7	Vigorous, fairly well spurred
,,	,, D3	1	6	14·3	10·8	13·2	
Comice	Quince A	1	11	11·9	5·9	10·7	Medium vigour, slender, well spurred
,,	,,	2	6	12·2	6·2	11·0	
,,	Quince C	1	10	9·6	4·3	8·0	Fair vigour, slender, well spurred
,,	,,	2	13	10·5	5·3	9·0	
,,	Pear B1	1	6	13·5	8·9	13·7	Vigorous, slender, sparsely spurred
,,	,, D3	1	6	13·5	8·6	15·5	do.
B. Bedford	Quince A	2	21	11·2	7·3	10·3	Medium vigour, erect well spurred
,,	Quince B	2	6	10·9	6·6	10·2	Fair vigour, erect, well spurred
,,	Quince C	2	11	9·6	5·6	8·6	Poor terminal growth, some defoliation
Bristol X	Quince A	2	5	11·2	7·9	10·6	Vigorous, prolific
,,	Quince B	2	10	10·5	7·6	9·3	Fair vigour, prolific
,,	Quince C	2	7	7·6	6·3	7·1	Little growth, brittle wood, prolific
Durondeau	Quince A	2	12	9·8	7·6	8·9	Fair vigour, well spurred and self-spurring
,,	Quince C	2	12	8·2	6·3	7·7	Fair vigour, some defoliation
Fertility	Quince A	1	11	9·6	5·6	7·9	Fair vigour, some defoliation, prolific
,,	Quince B	1	7	9·6	5·3	7·8	
B. Hardy	Quince A	1	12	14·2	12·2	14·8	Vigorous, sparsely spurred
,,	Quince C	1	11	12·6	8·2	12·2	Fair vigour, sparsely spurred
,,	Pear B1	1	6	16·1	13·8	17·9	Highly vigorous, v. sparsely spurred
,,	,, D3	1	6	15·8	13·5	19·2	do.
Guyot	Quince A	2	8	7·2	3·3	4·5	Poor vigour, heavily spurred
,,	Quince C	2	9	7·6	3·3	5·4	Very poor vigour. No terminal growth. Heavily spurred
Superb	Quince A	1	6	12·4	6·3	11·7	Vigorous, freely spurred
,,	Quince B	1	6	12·4	6·0	11·6	do.

in habit. The trees recorded as scion rooted on this plot have been excavated to confirm the presence of scion roots, but it cannot be said with any certainty that they are the only ones so rooted.

Scion rooting leads to a much invigorated tree, shoot growth increases and takes on a decided upright trend, whilst the leaves remain green and function on the tree much later than comparable trees not scion rooted.

Scion rooting has been confirmed in 11 out of 537 trees planted originally on the plot. They are distributed as follows :—

Bristol Cross on Quince C(1), Beurre Bedford on Quince G(1), Doyenne du Comice on Quince G(1), Fertility on Quince B(1), Dr. Jules Guyot on Quince C(2), William's Bon Chretien on Quince C(4), Williams' Bon Chretien on Quince A(1), making a total of 11 trees, confirmed scion rooted.

Scion rooted trees have been considered as casualties for the purpose of further recording.

Tree Size.

Table II sets out the mean height, spread and girth recorded in the winter of 1944, of each of the 10 varieties grown on the several rootstocks. The varieties are very unevenly spread over the three Quince and the three layered seedling rootstocks and complete comparisons are therefore impossible. Relative performance is shown, however, of most varieties on Quince A and Quince C, and in all cases but one (Guyot) the size of trees on Quince A expressed in girth and height is appreciably greater than trees on Quince C. This position is not always maintained when spread is taken into account, the early fruiting of varieties on Quince C tending to give a flattened, more spreading tree.

Trees of Beurre Hardy are outstandingly bigger than those of any other variety on the plot, irrespective of rootstock, whilst trees of Dr. Jules Guyot are small and unsatisfactory and like the variety William's Bon Chretien should not be " worked " direct on Quince by reason of incompatibility of stock and scion.

Blossom Dates.

The recording of blossom categories each year necessitates visiting the plot each day over an extended period, as every tree of the same variety on the several rootstocks does not expand its blossom buds on the same day. Different varieties, too, have their own blossoming periods.

The period taken therefore to record blossom categories for each variety on the various rootstocks extends over a number of days. This period has been noted and the record for each of the years 1940—1944 inclusive has been used to construct the blossom record chart. This chart shows the relative blossoming periods over the five seasons. Annual differences in blossoming time, *i.e.* early or late are clearly shown, but it is interesting to note that the same general order of flowering is preserved throughout.

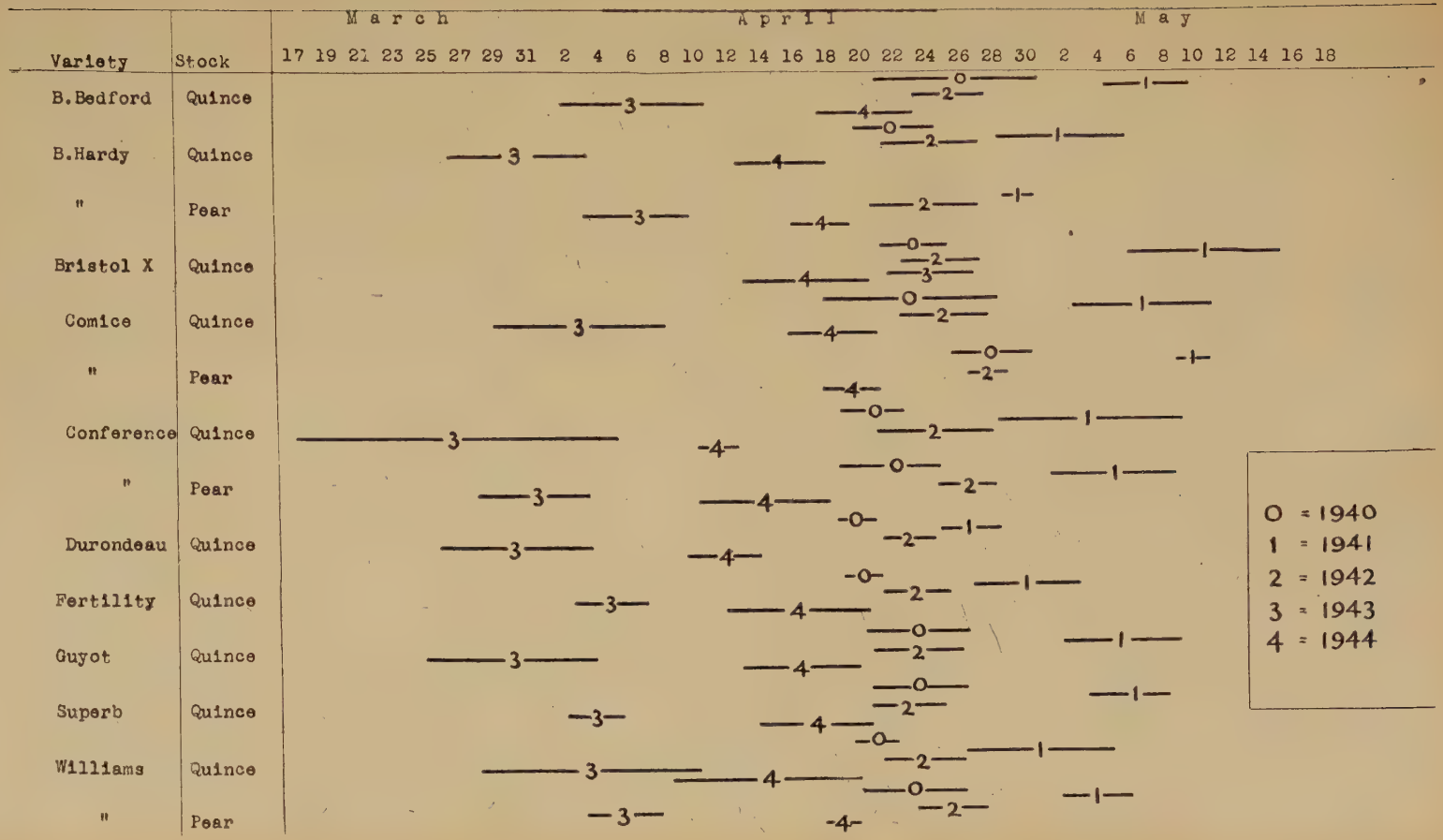
Picking Dates.

The picking dates of the ten varieties show them to fall into the following order of harvesting :—

(1) Superb, (2) Dr. Jules Guyot, William's Bon Chretien, (4) Beurre Bedford, (5) Beurre Hardy, Fertility, (7) Conference, Bristol Cross, (9) Durondeau, (10) Doyenne du Comice.

Early season varieties have been picked whilst in firm condition, but Conference and Bristol Cross have been left on the trees until changing colour indicated the approach of ripening. Doyenne du Comice has been left on the trees as long as possible.

BLOSSOMING RECORDS, 1940-1944.



All varieties on Quince C have been ready for picking appreciably earlier than on Quince A, and slightly earlier than as on Quince B, whilst the fruit of all varieties on the layered seedling Stocks B1 and D3 in particular have been appreciably later.

Cropping.

The mean crop yields per tree of each variety for the years 1940—1944 inclusive are set out in Table III. It is unfortunate that here again a comparison of performance of all varieties on all stocks cannot be given.

The crop figures show, however, the cropping potential of each of the varieties on Quince A and of 8 varieties on Quince C. Three varieties only are represented on the layered seedling stocks B1 and D3.

Doyenne du Comice has lagged far behind all other varieties in yield. Dr. Jules Guyot and Beurre Hardy cropped somewhat heavier, but gave far less crop than the other seven varieties.

In the case of Dr. Jules Guyot the trees are too small to carry much fruit, whilst the very vigorous growth of Beurre Hardy does not predispose to heavy fruiting.

The performance of William's Bon Chretien on Stock B1 and D3 augurs well for the future, and shows that this variety can fruit well when worked direct on to pear stock, possibly obviating the necessity of " double working " the variety on to Quince to get early returns.

Girth.

Trees worked on the layered seedling rootstocks B1 and D3 have produced trees markedly bigger than those on any of the Quince rootstocks and also bigger than on " Hiller " layered seedling.

Of the Quince stocks, Quince A has produced trees outstandingly more vigorous than Quince B or C. Quince C has given the smallest trees of all varieties on all stocks.

Spread and Height.

Early cropping and weight of crop can increase spread and decrease height considerably.

In the case of Conference trees on Quince C, the mean spread is greater than that of trees on the other rootstocks, including the layered seedlings, whilst the height figure is the lowest for trees on all rootstocks.

In view of the planting distance of 15 x 12 feet, it is interesting to note that Conference trees on Quince C are approaching the smaller figure, as also are trees on layered seedlings B1 and D3. In the former case, however, overcrowding does not seem probable for some years to come, whereas in the latter case a few years of heavy cropping would, by weighing down the branches, increase spread sufficiently to cause adjacent trees to touch across the rows.

Cropping.

The mean number and weight of fruits per tree picked during the years 1940–44 inclusive is shown in Table III.

Crop weights for each separate year are not shown, but the weights elsewhere recorded for 1940, 1941, and 1942 show the precocity of trees worked on Quince C.

In 1943 the crop from trees on Quince A and Quince B equalled that of trees on Quince C, whilst a marked increase was shown for trees on the layered seedling rootstocks.

TABLE III.

CROP WEIGHTS PER TREE (TOTALS 1940—1944).

Rootstock :— Variety	Age at planting (yr.)	Quince						Pear					
		A		B		C		B1		D3		Hiller	
		No. of fruits	Wt. (lb.)	No. of fruits	Wt. (lb.)	No. of fruits	Wt. (lb.)	No. of fruits	Wt. (lb.)	No. of fruits	Wt. (lb.)	No. of fruits	Wt. (lb.)
Conference	1	144	43·3	99	31·2	214	62·7	139	40·0	167	49·5	168	50·6
,, ...	2	186	62·9	153	47·1	196	60·1						
Williams	1	372	99·4	322	88·7	10	2·9	291	75·9	515	128·3		
,, ...	2			346	94·8	143	38·3						
Comice	1	36	14·3			45	17·6	1*	0·2	7*	2·6		
,, ...	2	48	18·3			87	35·9						
B. Bedford	2	372	119·0	352	120·6	327	110·2						
Bristol X	2	419	122·3	383	106·9	465	119·0						
Durondeau	2	285	104·9			297	87·1						
Fertility	1	772	106·7	715	116·2								
B. Hardy	1	155	45·5			199	57·9	11	3·1	9	2·2		
Guyot	2	104	26·8			129	33·9						
Superb	1	372	92·4	345	92·0								

* Total for 6 trees.

In 1944 trees on Quince C lost their lead, especially to trees on the more vigorous layered seedling rootstocks.

It seems possible, therefore, that the total weight of crop produced by trees on Quince may be exceeded by that of the larger trees on the layered seedling rootstocks within the next few years.

Discussion.

The data presented in this report show the very great differences to be expected if a plantation of pears is planted on mixed Quince rootstocks and also the considerable differences of tree size and cropping to be expected between different varieties growing on the same rootstock.

The biggest trees on the plot, for example, are of Beurre Hardy, whether on Quince or layered seedling rootstock. Trees of this variety on layered seedling rootstocks, planted alternately with a tree on Quince between were in 1944 growing into the intermediate tree which in a few years time will be crowded out.

The smallest trees are of the varieties Fertility, Dr. Jules Guyot and William's Bon Chretien. The latter two varieties should not be worked directly on to Quince in any case, but Fertility might be included in a bush pear plantation with other varieties. It would be important, therefore, to visualise probable tree size in say 10–20 years time in order to allow of an economical yet ample spacing of the trees.

The loss of 29 out of 30 trees worked on Quince G, whilst the varieties concerned suffered comparatively few losses on Quince A, B and C, would seem to show a marked degree of incompatibility peculiar to this selection of Quince. Trees on this stock made little progress in growth and failed to produce a framework of any size. The one surviving tree, Beurre Bedford, shows marked signs of scion rooting.

The heaviest crops have been produced by varieties Beurre Bedford and Bristol Cross on Quince and by William's Bon Chretien on the layered seedling rootstocks B1 and D3. The known shyness of Doyenne du Comice to crop is shown in the case of two Quince and two layered seedling rootstocks.

The figures for the mixed varieties are not conclusive, however, as the varieties grown are not distributed evenly over the rootstocks used, neither are the trees represented in comparable numbers.

Conference has made good trees on all rootstocks excepting Quince G, and its yield to date has been highest from trees on Quince C.

THE PREVENTION OF PRE-HARVEST DROP IN APPLES.

By T. SWARBRICK.

Introduction.

Accounts of earlier work on this subject have been given in the Long Ashton Annual Reports for 1941 and 1942. In 1941 (1) trees of the variety King Edward VII were sprayed with alpha-naphthalene-acetic acid at 5 and 10 parts per million in water. The higher concentration reduced pre-harvest drop by 15% despite a gale of 50 miles an hour. The drop from the pruned trees was less than that from unpruned trees, due probably to the better cover obtained during spraying. In 1942 (2) the trials were extended to include a

new compound, *viz.* naphthoxy-acetic acid, and the apple variety Allington Pippin. In the 1942 trials no benefit was obtained with either substance on the variety King Edward VII, but a satisfactory result was obtained with Allington Pippin. Alpha-naphthalene-acetic acid proved to be the better of the two substances.

The present work is a continuation of these earlier trials, using only naphthalene-acetic acid on the variety Beauty of Bath. Two more new compounds were also included in the trials on Worcester Pearmain. The results presented suggest that where the necessity arises the prevention of pre-harvest drop is now a practical proposition in this country.

Materials and Methods.

Beauty of Bath.

The trees were 20 years old growing on the rootstock M.I. Half of them were growing in grass sod, the other half under clean cultivation. This particular variety was selected for trial because under Long Ashton conditions it habitually drops the bulk of its crop long before the fruit is of good marketable quality. Only one substance—viz. alpha-naphthalene-acetic acid, was used on these trees and only one application was made to each tree.

The material was applied as a spray during the early afternoon of July 18th, 1944, using 15 parts per million of n.a.a. plus 1½ pints of ester salts per 100 gallons of water. A pressure of 300 lbs. per square inch was used to apply a heavy cover of about 5 gallons per tree. The weather was warm and settled with a mid-day temperature of 70° F. There was no rain until eleven days after the spray had been applied, nor were there any unduly high winds during the period of the experiment. The above date of application was selected as being about 8–10 days before the fruit would normally be expected to show a heavy drop.

From July 24th onwards—*i.e.* a week after spraying, the fruit under each tree was picked up separately, weighed and counted. The trees, including controls, were divided into three groups. One group was picked on August 3rd, the date when under ordinary circumstances the crop would have been picked in order to minimise loss from pre-harvest drop. The second group comprising the majority of the trees was picked on August 10th, by which time the fruit on the sprayed trees was fully developed and of first-class quality. The third group of trees was allowed to carry its fruit until it fell naturally.

Worcester Pearmain.

These trees comprised a block of 48 trees, four trees on each of the rootstocks M.I, II, III, IV, V, VII, IX, X, XII, XIII and Bristol G8. One tree on each rootstock was included in each of the four following treatments :— (1) Control, (2) Alpha-naphthalene-acetic acid, (3) Beta-naphthoxy-acetic acid, (4) 2–4 dichloro-phenoxy-acetic acid. Only one application was made to each tree.

The sprays were applied on August 21st, 1944, during the early afternoon, using 15 p.p.m. of each substance. The mid-day temperature was only 62° F., and a strong S.W. wind was blowing which made spraying very difficult. The difficult weather conditions were responsible for certain irregularities in results.

The crop was harvested on September 26th, which was about 14 days after the Worcester crop had been picked on the rest of the farm. During the period between spraying and harvesting all fruits were picked up and recorded for each tree. The weather during the period between spraying and harvesting was rather squally, with cold periods of rain.

Results.

Beauty of Bath.

TABLE I.

SHOWING THE CROP AND THE PERCENTAGE FRUIT DROP FROM TREES OF BEAUTY OF BATH DURING THE PERIOD JULY 24TH—AUGUST 10TH, 1944.

Tree Number and Treatment.		Total Crop.	Total Drop.	% Drop Aug. 3rd.	% Drop Aug. 5th.	% Drop Aug. 10th.
Control Tree	1 ..	1043	308	29·5	—	—
	3 ..	946	323	34·1	—	—
Treated	4 ..	650	20	3·1	—	—
	5 ..	640	25	3·9	—	—
	6 ..	661	16	2·4	—	—
	7 ..	717	27	3·8	—	—
	8 ..	822	27	3·2	—	—
Control	18 ..	884	809	—	62·7	91·5
	19 ..	1308	1158	—	48·7	88·6
	20 ..	1258	1183	—	44·3	94·0
Treated	10 ..	785	110	—	6·4	14·0
	11 ..	357	72	—	8·1	20·2
	12 ..	311	71	—	9·3	22·8
	13 ..	735	168	—	8·4	22·3
	15 ..	765	120	—	7·1	15·7
	16 ..	761	71	—	4·7	9·3

The data are set out in Tables I and II. Considering first the eight trees picked on August 3rd, the unsprayed trees had by this date dropped 30% of their total crop despite the fact that the apples were far from being ripe. The sprayed trees, however, had dropped only 4% of their total crop. The treatment had reduced the drop from one-third to one-twenty-fifth.

A further nine trees were picked on August 10th, that is three weeks after spraying treatment. The unsprayed trees had then dropped 90%, while the sprayed trees had dropped only 18% of their total crop. By this date the fruit on the sprayed trees was fully ripe and had developed a brilliant colour and excellent flavour. It was in fact first-class quality produce. On the other hand the 10% of fruit still remaining on the untreated trees was of inferior quality and almost worthless.

Since drops were picked up daily it is easy to calculate the percentage of fruit that had fallen at any given date. Assuming that fair quality fruit was desired, then the crop could have been picked on August 5th. On this date, the unsprayed trees had dropped approximately 52% of their total crop, whereas the sprayed trees had dropped only 8% of their total crop, a saving of about 50 lbs. of fruit per tree or about two tons per acre.

Two sprayed trees were left unpicked with the intention of allowing their crop to fall naturally. A drop of ten to fifteen apples per day continued over the period up to August 25th. By this time most of the fruit still remaining on the treated trees had become "mealy ripe" and had split open. These splits consisted of 3 or 4 deep clefts running radially from the cavity towards the eye. When these apples fell it was not due to normal abscission, since the apples fell away leaving the peduncles still firmly attached to the tree. This splitting of the fruits prior to falling was general for all fruit left to hang an abnormally long time on the treated trees, but was never observed in control trees where the fruit fell naturally before it was even eating ripe. It should be noted, of course, that the control trees had dropped all their fruit by August 14th. Some fruits were retained on the sprayed tree until September 24th, 1944, that is for over five weeks longer than normal.

TABLE II.

Showing the Daily Drop of Fruits from two Typical Control and Treated Trees.

Tree Number and Treatment.	July.							August.							
	24	25	26	27	28	29	31	1	2	3	4	5	8	9	10
Control Tree 18 ..	6	7	4	8	36	25	55	73	70	100	99	73	192	29	34
20 ..	8	1	5	10	10	15	41	46	67	96	140	118	438	89	99
Treated Tree 10 ..	7	3	0	1	1	3	4	7	9	2	7	6	38	6	16
11 ..	3	3	2	0	1	1	3	3	2	7	2	2	21	7	15

Data given in Table II show that the normal fruit drop began on the untreated trees about July 27–28, that is about ten days after the spray had been applied to the remaining trees. The severity of the drop increased rapidly the next few days, so that by the beginning of August the daily drop was upwards of a hundred fruits a day. The drop from the treated trees remained at a low level right up to August 10th, when the crop was picked from these trees. There is, however, a slightly increased drop from early August to the time of picking. The very high figure recorded on August 8th is accounted for by the fact that it covers a week-end during which there was a strong wind for some hours on the Sunday night. It is interesting to note from the data of Table II that the spray application was well timed, in that it was made within ten days of the normal drop from the untreated trees.

The importance of thorough coverage is shown by observations made on tree 14. On August 1st it was noticed that there was a very heavy drop of fruit from the S.E. quarter of this particular tree. By August 10th almost every fruit had fallen from this part of the tree, whereas practically nothing had fallen from the remaining three quarters. The method of spraying these trees necessitated the operators pulling their pipe lines between each tree, and it is almost certain that this part of the tree was left unsprayed. The observation provides further evidence that there is no general effect over the tree as a whole. In order to be effective every fruit must be covered with the spray fluid.

In conclusion it is pointed out that cultural conditions have not affected the result. The material was equally effective on trees growing in grass sod mulch and under conditions of clean cultivation.

Worcester Pearmain.

TABLE III.

SHOWING THE PERCENTAGE FRUIT DROP (AUG. 21—SEPT. 26) FROM INDIVIDUAL TREE OF WORCESTER PEARMAIN RECEIVING DIFFERENT TREATMENTS.

Untreated. (Control).	Alpha-naphthalene-acetic acid.	Beta-naphthoxy-acetic acid.	2–4 dichloro-phenoxyacetic acid.
80·9	37·2	83·0	70·1
52·6	41·5	74·7	69·8
82·5	33·9	71·3	65·4
78·4	48·2	90·3	65·3
77·4	54·3	88·2	78·9
73·2	43·8	84·2	83·6
82·5	49·7	86·0	94·8
86·5	34·2	91·3	93·3
88·9	59·4	86·8	52·2
93·0	53·0	—	87·1
88·3	—	—	94·9
—	—	—	81·9
Average 80%	45%	84%	78%

The results obtained with this variety are set out in Table III. Table III gives the percentage fruit drop from a number of trees each receiving one of four treatments. The data shows that of the three substances tried, only Alpha-naphthalene-acetic acid has reduced fruit drop. The drop has been reduced from 70% in the control trees down to 45% in trees treated with alpha-naphthalene-acetic acid. It is important to notice that the period covered by these trials extended for almost three weeks beyond the normal picking date for this variety at Long Ashton.

An examination of individual tree data shows that the really heavy fruit drop in the unsprayed (control) trees began about September 15th, 1944, which is the time when the picking of this variety would normally have been finished. From this time onward the unsprayed trees showed a heavy daily drop.

Apart from the reduction in fruit drop secured by the use of naphthalene-acetic acid and the failure of the two other compounds, the most important point to note is that this result has been obtained under unfavourable weather conditions. The weather throughout the period was cool and squally with occasional heavy rainstorms. In view of these adverse weather conditions the good results obtained stress the effectiveness of alpha-naphthalene-acetic acid as a preventive of pre-harvest drop.

The effect of the extra fourteen days' development upon the quality of the fruit was most marked. The apples were brilliantly finished and were in fact the best quality fruit of this variety that we have ever produced at this Station. They had a clean fresh flavour, more aromatic than is usual for this sort. They were crisp in texture, sweet and juicy, and without that tendency to woolliness so frequent in Worcester Pearmain.

General Discussion and Conclusions.

The present trials confirm previous experience both at East Malling (5), Long Ashton (1, 4), and in America (3, 5) that alpha-naphthalene-acetic acid can be relied upon to prevent or delay pre-harvest drop of apples when used correctly. Although two other growth-promoting substances have been tried they have not given consistent results and cannot at present be recommended.

Throughout the trials at Long Ashton only a single application of the substance has been made. As far as possible this has been applied within ten days of the time when the heavy fruit drop was normally expected to begin. This timing is based upon the work and experience of the American workers. A concentration of 10–20 p.p.m. of the substance has proved effective, even in 1944 when low temperature and rainy periods prevailed during the trials.

The extraordinary effect which alpha-naphthalene-acetic acid may have upon fruit retention is shown in the Beauty of Bath apples which, when left alone, went through their complete ripening cycle while still attached to the tree. Many of these fruits split open and fell, leaving their fruit stalks still firmly held onto the tree. Such a phenomenon has never been observed on untreated fruits.

The sprayed fruits of Worcester Pearmain were many of them still very firmly attached when picking was in progress. This raises the whole question of obtaining durability without increasing firmness. Obviously what is mostly required is duration of the effect since, if the fruits are held on too securely, much damage may be caused to the spur system at picking time.

In the two dessert varieties under trial, spraying to prevent pre-harvest drop has not only reduced the drop, it has given improved fruit quality. The extra period on the tree is undoubtedly responsible for this marked effect. Every apple of the treated trees was of really first-class quality when picked, and in normal times would have commanded the very highest prices. This point is of the greatest possible economic importance. In fact the use of pre-harvest drop sprays may be justified on this aspect alone.

The importance of complete coverage cannot be over-emphasised. Any part of the tree which is not sprayed is not protected. All observations indicate that there is no spread of the effect even over short distances. In order to obtain protection the substance must actually come into contact with the apple, particularly its stalk.

It is not proposed at this stage to discuss the economics of the use of substances to prevent pre-harvest drop. A great deal will depend upon the general efficiency of the grower and the cost of the materials. At present alphha-napthalene-acetic acid is available only as a fine chemical in small quantities, but as the demand increases it should become more readily available at reduced cost. In this connection it may be pointed out that the spraying of Beauty of Bath not only saved some two tons of fruit per acre, but materially increased the value of the whole crop. In normal times when quality will determine price this aspect must receive much greater consideration. The spread of picking labour, which may be obtained from the use of pre-harvest drop sprays, must also be considered, although it may be difficult to rate this advantage upon a cash basis.

In conclusion it is clear that satisfactory materials and methods are now available for the prevention of pre-harvest drop. New or better substances and methods may be forthcoming at any time, but in the meantime growers

who find pre-harvest drop an economic disadvantage can now adopt effective routine methods for its reduction.

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THE USE OF GROWTH-PROMOTING SUBSTANCES AS A MEANS OF INDUCING FRUIT SET AND DEVELOPMENT IN THE TOMATO.

By T. SWARBRICK.

Introduction.

In recent years American workers, notably Gustafson (1) and Zimmerman and Hitchcock (6) have shown that certain chemicals will cause the development of unfertilised tomato fruits. Similar work has been in progress at Long Ashton for a number of years. Until recently the substances known to be effective have been limited, but in 1944 Zimmerman and Hitchcock (6) reported the use of new compounds, some of which were effective at very low concentrations.

In 1943 (4) a progress report was made showing that by the application of beta-naphthoxy-acetic acid (N.O.A.) to Tardive de Leopold strawberries in the field, the yield of fruit was significantly increased. The present paper reports a number of experiments with tomato carried out during 1944 and 1945, and falls into two parts. The first is a trial of four substances at two concentrations. The second deals with the results obtained from a trial of the two most effective substances at dilutions of from 30 p.p.m. down to one part of substance in five million of water.

In a subject so new as this one, it is not surprising that unexpected results should appear. Indeed a number of isolated observations have been recorded which, while they are thought to be important, must be treated with caution. The results obtained have immediate and practical application to the production of tomatoes as an out-of-season crop, but the original object was to investigate the fundamental problems involved in fruit setting and development. The present paper therefore sets out results obtained from experiments planned on academic rather than practical lines.

Some of the results are highly spectacular, but it is clear that unknown factors may be important. Technique is of great importance. There is one stage of floral development at which the maximum effect can be obtained with the minimum concentration of effective substance. In the interpretation and practical application of the results of these and similar experiments the importance of procedure and technique must be kept clearly in mind, since two widely different results were obtained by applying the same concentration of the same substance by two different methods.

Summer Trials, 1944.

Materials and Methods.

For the summer trials of 1944 plants of Market King were set out into ten-inch pots in the normal manner. The plants were then divided into two

groups, some going into one house as controls, the remainder into the adjoining house for treatment. The youngest flowers of the first trusses of these plants were fully expanded on April 5th, 1944. On this date the sepals, petals and stamens of all the treated plants were removed by grasping the calyx tube between the finger and thumb of the right hand and pulling, while supporting the flower stalk, with the left hand. The extra-ovarian floral parts of all treated plants were removed in this way as and when they were fully expanded. This was an experimental refinement, in order to prevent any natural pollination, so that any fruits which developed on these treated plants must of necessity be the result of some artificial stimulation.

Four substances were used in these trials, viz. (1) Alpha-naphthalene-acetic acid (N.A.A.); (2) beta-naphthoxy-acetic acid (N.O.A.); (3) 2-4 and (4) 2-6 dichlorophenoxy-acetic acid (2-4 D and 2-6 D). These four substances were all used at two concentrations, viz. 10 and 100 parts per million (p.p.m.). Since these four substances are insoluble in water the following procedure was adopted. A 10% solution of the substance was made up in 95% alcohol. From this the necessary dilutions were prepared by adding the alcohol solution to tap water to which sufficient Ester Salts had been added to give satisfactory wetting of the foliage. Experience shows that tomato flowers are difficult to wet, and in order to get satisfactory results complete wetting is essential.

The diluted solution was applied to the flower trusses by means of a small glass atomiser, using only sufficient spray to thoroughly wet the flower truss. Where necessary the spray should be directed so that it falls on the ovary, which is very small and lies at the base of a deep calyx cup. In these trials only one application was made to each flower truss. This was made as soon as the last well developed flower on the truss had been emasculated as described above. By this method very small quantities of substance are used, and it is not difficult to prevent it coming into contact with the rest of the plant.

A group of emasculated plants was left untreated. These plants are distinct from the "controls" in that they had all their flower parts removed except the ovaries, whereas the control plants were treated normally in every way. All plants were stopped after the production of the fourth truss.

Results.

1. *Effect upon Total Yield.*

The data are given in Table I. This shows that the mean yield of the control plants was 81 ozs. from the four trusses. In view of the general conditions of the experiment this must be regarded as satisfactory and provides a firm basis for comparison.

The mean yield from the emasculated "untreated" plants was only 16 ozs., made up entirely of small "chat" fruits of less than ½ oz. each. Most of these small fruits developed on the two upper trusses, due presumably to small quantities of the growth substances reaching these trusses during the treatment of adjoining plants.

Alpha-naphthalene-acetic acid (N.A.A.) failed to induce a reasonable production of fruit even at the very high concentration of 100 p.p.m. The mean yield of 28 and 32 ozs. per plant was made up of small fruits, the largest of which was only 1½ ozs.

The other three substances all produced substantial yields. Beta-naphthoxyacetic acid (N.O.A.) induced yields of 66 and 70 ozs. per plant, 2-4-dichlorophenoxy-acetic acid (2-4 D), 83 and 68, and 2-6-dichlorophenoxy-acetic acid (2-6 D), 70 and 84 ozs. when used at 10 and 100 p.p.m. respectively.

It appears therefore that N.O.A., 2-4 D and 2-6 D have produced satisfactory yields of fruit without pollination, while N.A.A. has proved useless in this respect. Furthermore, the data shows that in these trials no benefit was obtained by using the higher concentrations. Indeed it will be shown later that certain undesirable results may follow the use of high concentrations of 2-4 and 2-6 D. N.O.A. on the other hand is less likely to give these undesirable results even when used at high concentrations.

TABLE I.

Showing the Average Yield per Truss from Four Plants under each of the Following Treatments. Plants stopped at Four Trusses each.

	Yield in ozs.				
	First Truss	Second Truss	Third Truss	Fourth Truss	Total mean yield per plant
Control	19	21	22	19	81
Emasculated Untreated	Small n	umber of	Chats to	talling	16
Alpha-naphthalene-acetic acid 10 p.p.m.. .	3	13	8	8	32
Alpha-naphthalene-acetic acid 100 p.p.m.	8	8	6	6	28
Beta-naphthoxy-acetic acid 10 p.p.m. ..	21	18	13	15	67
Beta-naphthoxy-acetic acid 100 p.p.m. ..	21	17	9	24	71
2-4 dichlorophenoxy-acetic acid 10 p.p.m.	29	24	13	19	85
2-4 dichlorophenoxy-acetic acid 100 p.p.m.	17	11	23	15	66
2-6 dichlorophenoxy-acetic acid 10 p.p.m.	20	17	16	19	72
2-6 dichlorophenoxy-acetic acid 100 p.p.m.	27	15	29	12	83

2. *Effect upon Fruit Size and Development.*

All the fruits produced on plants emasculated and subsequently treated with growth promoting substances as described above, were seedless. A photograph of cross sections of normal and artificially produced fruits is shown in Figure 1.

The seedless artificially produced fruits are approximately the same size as normal ones. Three types of seedless fruit have been found. The majority are filled with the usual mucilaginous material and except that they are seedless are like normal tomatoes in appearance. A second group is more or less solid. The central part is made up of a mass of firm red fleshy tissue similar to that which normally makes up the outer fleshy casing of the tomato. A third group is partially hollow, the outer casing being separated from the central area. In this case the gelatinous material has failed to develop, a condition for which no explanation is at present available, except that the hollow fruits invariably occur on plants treated with 2-4 D. N.O.A. has so far never given rise to this hollow type of fruit. (See Fig. 1.)

Figure 2 shows a typical plant the fruit of which has been produced by spraying the emasculated flowers with N.O.A. at 100 p.p.m. It should be noted that all the fruits are more or less the same size, secondly that the fruits of the three lower trusses are all at the same stage of ripeness, thirdly that

almost every flower has been induced to develop into a fruit. At the time this photograph was taken a few fruits had been picked from the three lower trusses.

The uniform size and ripening of the artificially produced fruits is due to the technique employed in these trials. Each truss received only one application of the growth substance, which was delayed until the youngest flower of the truss was fully developed. It will be seen that by this method a considerable time elapsed between the emasculation of the older flowers of the truss and the application of the growth promoting substance, but that the fruits of any one truss all started development on the same date, *i.e.* the date of application. The fruits of one truss are therefore physiologically of the same age.

In the plant shown in Figure 2 the three lower trusses were all treated on the same date, viz. April 27th, 1944. The bottom truss of this plant finished flowering on April 6th, so that fruit development of this truss was not initiated until three weeks after the flowers were ready for pollination. April 27th was the date at which the youngest flower of the third truss was ready for spraying. The whole of the fruits of the three lower trusses are therefore of the same "physiological" age. It is not surprising, therefore, that the fruit on these three trusses should be the same size and at the same stage of ripeness. The total crop of these three trusses was gathered within ten days and the whole crop of this plant within three weeks.

The effect of applying these growth promoting substances to flower trusses which have been emasculated for upwards of three weeks is immediate. In the plant shown in Figure 2 the spray application was made about 4.0 p.m. on the 27th April. By 9.0 a.m. on the 30th April the fruit had developed to the size of small peas, a really remarkable development in the time. This rapid initial development has been observed on many occasions throughout these trials, and the phenomenon is important both from the theoretical and practical points of view. A typical truss of such artificially produced fruit is shown in Figure 3 with a one inch scale for comparison. It should be noted that this photograph was taken on January 8th, 1945, from a truss treated Nov. 2, 1944. Its weight was 19½ ozs.

This telescoping of the crop into such a short ripening period presents a completely new problem in cultural management. Such development puts a severe strain upon plant economy and new methods of management will have to be devised so as to provide the necessary stimulus to continued growth and development while maturing crops.

Effect upon Fruit Quality.

The quality of the fruit produced by these synthetic growth substances was substantially equal to that produced by the normal method. Dr. Pollard of the Biochemical Section carried out a series of trials to determine the sugar, acid and vitamin C content of these fruits, and his results are published elsewhere in this report. His examination shows that the parthenocarpic fruits are not significantly different from normal fruits as regards sugar, acidity and vitamin C content.

The palate on the other hand was able to detect certain differences. The fruits were submitted to a considerable number of people during the summer of 1944. Those used to the taste of fresh well-grown tomatoes allowed to ripen naturally on the plant invariably preferred the normal tomatoes. On the other hand persons who normally purchase their tomatoes from retail

stores almost invariably preferred the artificially produced fruits. To the palate these latter were less acid, sweeter, more mellow, slightly insipid and devoid of outstanding flavour or character. The flesh was more mealy in texture and less crisp than that of normal tomatoes. The difference was that between an outdoor and a greenhouse grown fruit of the same variety. It was possible in this way to distinguish between the fruits of the same variety produced by 2-4 D and N.O.A. The former were of a more mealy texture, less succulent and with a tougher skin. The latter were more watery, sweeter than normal, thin skinned and rather insipid in flavour. The mucilaginous material of these latter fruits frequently contained large quantities of chlorophyll.

All fruits harvested from control plants had either bilocular or trilocular ovaries. On the other hand hormone produced fruits had loculi varying from one to many, trilocular being the most common. In spite of these differences the artificially produced fruits were of good quality, colour, and appearance.

Effect upon Plant Growth and Development.

It was pointed out earlier that no improvement in yield or " set " was obtained by using the higher concentrations of 100 p.p.m. of 2-4 D and 2-6 D as against the more usual one of 10 p.p.m. In fact it was found that these two substances induced malformation of both leaves and fruit when used at high concentrations. When applying the spray to an individual flower truss some of the material may escape into the atmosphere particularly when spraying the top trusses. This may not be serious if low concentrations are being used, but may be disastrous if the concentration is higher than 5 p.p.m., depending upon method of application and condition of plant.

The evidence suggests that when high concentrations of 100 p.p.m. were used, even when applied only to individual trusses, sufficient of the substance was absorbed by the plant to cause undesirable effects upon subsequent growth. A typical plant treated with 2-4 D at 100 p.p.m. is shown in Figure 4. Notice that the lower part of the plant, which was formed before the material was applied, is normal. The development of the upper part is abnormal. The leaves are severely " Frenched " and appear similar in many respects to these produced on certain types of virus diseased plants. Notice also that the fruits of the top truss are elongated and pointed. In fact, quite apart from any influence upon plant growth, the fruits produced under the influence of 2-4 D and 2-6 D are frequently ox heart shaped, pointed or beaked due to the development of the base of the style. N.O.A. induced fruit, although it may be beaked in the early stages of development, loses this condition during development, leaving the fruit normal in shape at maturity.

Autumn Trials, 1944.

The following trials were carried out during the autumn and winter of 1944, and are a development of these reported earlier in this paper. The main object was to determine the minimum concentration of growth substance necessary for the successful production of a crop of parthenocarpic fruit.

The problems of winter tomato production need no elaboration at this point. They consist essentially of getting fruits to develop from flowers produced during the short daylight period. It is not difficult to get the plants to flower during winter, but in spite of the transfer of pollen from one plant to another fruit development is erratic. In considering the results of these trials it must be remembered that they were carried out during the Autumn and Winter, and in this respect are subject to the limiting effects of light and

heat, together with physiological conditions which are very different from these prevailing during the earlier trial.

Materials and Methods.

Plants of the variety " Ailsa Craig " were set out into 10" pots on September 1st, 1944, and grown on in the normal manner. The layout of the plants in the greenhouse was similar to that described for the summer trials.

In these trials the two most effective substances, *e.g.* N.O.A. and 2-4 D, were used at the following concentrations in parts per million, 10, 5, 2·5, 1, 0·5 and 0·2.

The materials were prepared as described earlier and applied by the same method. All treated plants were emasculated as and when required to prevent natural pollination. Each truss received only one spray application, made about two days after the youngest flowers was fully developed, except that in some cases the distal flowers of the truss were obviously not going to develop in which case the youngest well-formed flower was used as the criterion.

The plants were grown throughout under normal winter greenhouse conditions, with a temperature range between 60 and 70° F. All plants were stopped at the 5th truss.

Results.

Effects on Yield.

The average yield per plant (2 plants per treatment) is set out in Table II.

TABLE II.

Showing the Average Yield per Plant for Several Concentrations of Growth Substance.

Concentration	2-4-dichlorophenoxy-acetic acid		Beta-naphthoxy-acetic acid	
	No.	Wgt. (oz)	No.	Wgt. (oz)
10 parts per million	22	28	22	33
5 „ „ „	25	32	18	32
2½ „ „ „	24	37	25	30
1 „ „ „	30	41	17	19
1 part in two million	24	32	10	10
1 „ „ five	26	36	15	18

The data show that quite reasonable winter crops of fruit were obtained by treating emasculated plants with various concentrations of growth promoting substances.

It should be noted that 2-4 D shows no positive correlation between yield and concentration. Indeed it would appear that this substance was as effective at one part in five million as at 10 p.p.m. General observation, however, would suggest that amount of daylight was a dominant factor and that a yield of 36—40 ozs. of fruit per plant was the physiological maximum under the particular conditions of this experiment.

N.O.A. on the other hand shows a marked fall in yield when used at less than 2½ parts per million. The upper limit of effectiveness for N.O.A. has not

yet been determined, but experience suggests that this will be much higher than the 10 p.p.m. used in the autumn trials, although it may be less than the 100 p.p.m. used in the summer ones.

It appears, therefore, that apart from the malformatory effects which 2-4 D may have and which will be discussed later, it is much more effective than is N.O.A. In these trials the latter ceased to be effective at 5 parts per million, whereas the former was effective at 1 part in five million. Previous work suggests that these are the minimum concentrations and that under less favourable conditions the higher concentrations will be required to produce a complete set of fruits.

The ability of these two compounds to initiate fruit development even after delays of up to a month was again clearly demonstrated. The first truss of these plants was in full flower on September 11th, 1944, but owing to previous commitments the spray was not applied until October 11th, so that there was an interval of 32 days between flowering and treatment. During this interval there was no sign of fruit development, yet within 48 hours of applying 2-4 D the ovaries showed marked swelling. In the case of N.O.A. it was 4-5 days. Subsequent growth and development was the same for both substances. It is clear, therefore, that even in early winter these two compounds will initiate the development of emasculated flowers even after a delay of 32 days.

The time interval between the hormone treatment and the maturation of the fruit was 55 days in these trials carried out during late autumn. This compared with 60 days for fruits produced on the control plants in an adjoining house.

Effect on Quality.

The differences in flavour and texture between normal and parthenocarpic fruits was less marked than it was in the summer trials. This was no doubt due to the prevailing winter conditions which reduced the general quality of all the fruits.

Phytocidal Effects.

Attention was called earlier to the so-called " malformative influences " of 2-4 D, an influence which detracts seriously from its usefulness in the present connection. When applied at 10 p.p.m. on to flower trusses or young foliage it causes severe epinasty from which they never recover. Furthermore, the fruits produced by its influence are frequently elongated and beaked with a strong tendency to hollowness. Beaked fruits are not necessarily hollow. At lower concentrations than 10 p.p.m. all these tendencies are reduced until at 1 p.p.m. no malformative effects are visible and the fruits produced are normal in shape and development except that they are seedless.

It was found in both the summer and autumn trials that 2-4 D and 2-6 D at 10 p.p.m. were damaging when applied to the unopened flower buds of the tomato. N.O.A. at the same concentration was much less harmful, although it was not so effective in inducing fruit set. This damaging effect of 2-4 D upon unopened flowers and young foliage is important, since it makes it impossible to treat individual flowers on a truss by the spray method. One such effect of spraying a truss too early can be seen in the lower truss of Figure 4. Note that the two oldest flowers of this truss developed and have been picked, but that the younger flowers failed to develop, although there was considerable epinasty and calyx development.

Effect of Age of Flower upon Response.

It has been pointed out that both 2-4 D and 2-6 D were damaging to unopened flower buds at concentrations above 10 p.p.m. It has been found that the best time to apply these substances is within a week following normal anthesis. Since the flowers of an individual truss develop in acropetal order the oldest ones may be 14 days old before the youngest ones are fully developed. The best time to spray a given truss must therefore be decided in each case, and where the plants are strong and vigorous with bold trusses, the spraying may be delayed until the youngest flowers are fully formed. Where the trusses are less vigorous spraying should be put forward and the youngest flowers neglected.

Experience over the last two years suggests that there may be other factors besides age of flower and concentration of material which determine the effectiveness of a particular substance. In some cases when materials known to be effective were applied at what was judged to be the right time, the ovaries failed to develop. At present no explanation of this phenomena is forthcoming, but it is a point which requires further investigation.

Winter Trials, 1944-45.

Materials and Methods.

The plants for this trial were set out in 10″ pots in a large orchard house in September, 1944. The first flower trusses were fully developed and treatments were started on November 9th, 1944.

This trial was intended to be a continuation with modifications of the autumn trial, but by an oversight the potting medium was not correctly prepared and the plants made poor growth and produced only weak flowers. Many of these flowers never opened but abscissed when only partially developed. The main object was therefore abandoned and the plants used for a somewhat different trial.

Apart from a wider range of concentrations of material, the main difference between this trial and the two former ones was in the method of application. Previously the material was carefully applied to the individual trusses by means of a small glass atomiser using the minimum quantity of spray necessary to obtain a complete wet of the sprayed parts. In the present trials the spray was applied by a pneumatic hand sprayer. A large sheet of cloth was held by a second operator behind the plant so as to prevent the spray reaching adjoining plants. Comparatively large quantities of spray were used, however, and large parts of the plant were wetted, so that the wash ran down the stems and on to the soil. By the time three trusses had been treated in this way the whole plant had received a liberal application of the wash. The lower parts had in fact received two or three complete wettings with time intervals of two to three weeks between them.

The results which are now described are considered due mainly to the large quantity of substance that was applied to these plants by this method, although the poor condition of the plants and the winter season may be contributing factors.

The substances used were 2-4 D at 5, $2\frac{1}{2}$, 1 and 0·5 parts per million and N.O.A. at 30, 15, 10 and 5 p.p.m. with various combinations of 2-4 D and N.O.A. at the above concentrations, *e.g.* 2-4 D at 5 p.p.m. plus N.O.A. at 30 p.p.m. and so on.

Results.

1. *Effect upon Fruit Set and Development.*

All the above concentrations of 2-4 D gave a partial set of fruit. From three to five fruits were developed on each of the three bottom trusses. These fruits developed rapidly but growth was confined almost entirely to the outer shell of tissue. Consequently they were hollow with a small central placentic region and no mucilage. Owing to this form of development the fruits, some of them up to four inches in diameter, were deeply convoluted and distorted. A typical truss of such fruits is shown in Figure 7.

In contrast to 2-4 D the plants treated with N.O.A. failed to set fruit at concentrations below 15 p.p.m. A set equal to that of 2-4 D at 5 p.p.m. was obtained with N.O.A. at 30 p.p.m. Of the plants treated with mixtures of 2-4 D and N.O.A., it was found that when 2-4 D had been included even at one part in two million there was malformation of the fruit and stunting of development. The effect was directly proportional to the concentration used.

So far as yield is concerned the winter trials have proved a failure, but this was due to the changed method of application and the poor plants and not a falling off in the effectiveness of the substances used.

2. *Malformative Effects upon Leaves and Stems.*

By this method of application the plants apparently absorbed large quantities of the growth substances, even from dilutions of 1 p.p.m. of 2-4 D. It was evident in 3—4 days that the plants were suffering severely and further applications were suspended after the three lower trusses had been treated. The plants were kept under constant observation with a view to determining their future development. The treated plants made little growth after mid-December. By early February the untreated plants were nearly three times the size of the treated ones. N.O.A. caused practically no epinasty, and at 30 p.p.m. was far less damaging than 2-4 D at 1 p.p.m.

The plants treated with 2-4 D at concentrations of 5 p.p.m. continued to produce abnormal "frenched" foliage for upwatds of 8 weeks after the last application of the substance. Furthermore, during this period some flower trusses were formed, and in many cases fruit developed parthenocarpically before the appearance of the petals and stamens. The developing "fruit" burst through the apex of the flower bud pushing its way through the middle of the flower. In this type of development the petals and stamens were much smaller than in a normal flower at the time of anthesis. (See Figure 5.) Parthenocarpic fruits were developed in unopened buds of the sixth and seventh trusses of these plants despite the fact that the application of growth substances ceased after the development of the third truss. All concentrations of 2-4 D used in these trials induced this development but it was not produced by N.O.A. at concentrations of less than 15 p.p.m.

It is interesting to note that some plants which were not so heavily treated with 2-4 D, although they produced malformed "frenched" foliage for a while, were producing normal foliage again by March 8th, 1945. The effect of the 2-4 D appears to have worn off. These plants now have a central region which has abnormal foliage although the upper and lower foliage is normal.

Spring Trials, 1945.

A group of 24 plants was left as controls in the Winter Trials 1944. Since these plants had not been treated in any way they provided material for a small trial in the spring of 1945. The main object of this trial was to ascertain

whether a return to the earlier procedure would give a fruit set without the undesirable malformations that occurred in the Winter Trials.

Treatments began on February 2nd, 1945. These plants were then about 4 feet high and had developed six flower trusses. Four of these were formed in winter 1944, the top one was just developing while the fifth truss was fully developed. Some of these plants were left as controls, others had their trusses sprayed with 2-4 D at 1 p.p.m., others were sprayed with N.O.A. at 30 and 15 p.p.m. The small atomiser was used as the method of application.

Result.

A typical planted treated with N.O.A. at 30 p.p.m. is shown in Figure 6 along with a control plant. Note that a good set of fruit has been obtained on three trusses. These were sprayed on February 2nd and photographed on March 8th, 1945. The untreated plants have not set any fruits despite the production of strong healthy flower trusses and the usual pollination transfer procedure.

The present indications are that a return to the earlier method of application has produced the same results as were obtained in the summer and autumn trials.

Discussion.

The most important point brought out by this work is that certain substances will initiate the development of fruits from flowers which have been emasculated and then allowed to remain untreated for upwards of three weeks. Of the two substances used, 2-4 D is the most effective but at concentrations of 10 p.p.m. or more it causes undesirable malformations of growth and development. N.O.A. must be used at much higher concentrations in order to have an equal effect upon fruit development, but the most satisfactory concentration of this substance has not yet been determined. In these trials all blossoms were emasculated in order to prevent natural pollination, but preliminary trials show that this is not necessary, although it is pointed out the substances are only effective when they actually come into contact with the ovary.

It would appear that the solution of the problem of poor setting in early and late greenhouse tomatoes is now only a matter of practical technique. Indeed, a recent publication by Roberts and Stuckmeyer (3) suggests that 2-4 dichlorophenoxy-propionic acid is as effective as 2-4 D in the production of parthenocarpic fruit, but is devoid of undesirable malformative effect. The present authors have so far failed to obtain a supply of this substance in this country so that trials with it have not yet been possible. Furthermore, recent American publications suggest that a number of new compounds are now available which may be even better than either 2-4 D or N.O.A.

The second point of importance is the relative effectiveness of the several substances. Naphthalene-acetic acid has proved useless. N.O.A. is much more effective and 2-4 D much more potent still. Not only are the substances of different value; they do not produce the same end point as regards flavour or internal structure. The small fruits produced by N.A.A. were invariably of the solid red fleshed type. The fruits produced by N.O.A. were almost normal in shape, were never hollow, and were filled with a dark green mucilage despite the fact that the outer shell of tissue was brilliant red and normal in texture. 2-4 D is outstanding in that the fruits produced by it are often more or less hollow and frequently elongated, egg-shaped and beaked. It appears that this compound has a more stimulating effect upon the outer shell of tissue and that it frequently fails to initiate the development of mucilage.

Although it is at present impossible to distinguish by chemical means between the fruits produced by these two substances, the palate can frequently do so with ease and certainty. The difference, for want of a better analysis, may be described as the difference between two varieties grown under the same conditions. This leads to the suggestion that varietal differences in flavour may be due to the growth substances that are involved in their production. In any case it is hardly likely that the natural hormones of pollen and ovary are either 2-4 D or N.O.A. These substances stimulate a development which at best approximates to that produced by the natural means.

It is necessary to recognise that fruits may be induced to " set," but that they may nevertheless fail to " develop." N.A.A. induced the flowers of tomato to " set," but the fruits did not develop beyond the size of walnuts. In field trials with apples and pears, 2-4 D, which has been shown to induce fruit development in tomato, caused many flowers to " set " when sprayed onto them at full bloom. In many cases every flower " set " but many of them fell during late June and early July, that is during the period of June drop. Many others, although they did not develop, remained firmly attached to the trees and were still present during winter pruning in January 1945. These fruits " set " but did not develop.

2-4 D has a strong tendency to stimulate development of the outer parts of the tomato fruit, so that in extreme cases such fruits are hollow, mis-shapen and deeply convoluted. Munson (2) reported in 1892 that in seedless egg plants the outer portions grew more rapidly than the inner portions, " the placenta evidently requiring the stimulus of the growing ovules to induce development." N.O.A. on the other hand gives rise to solid more or less normal shaped fruits except that they are seedless.

The part played by pollen in fruit setting and development should receive investigation from the present point of view. Pollen is essential for the production of seeds, but it has been shown in these and other experiments that it is not essential for the production of seedless fruits. It is suggested that in addition to chromosomes pollen may carry the material which provides the initial stimulus to fruit development, and that developing seeds may provide the remaining stimuli. In these experiments single substances were used whereas in nature there is no doubt that a succession of substances is involved, each one produced by a particular metabolic activity. These sequences must occur in a definite order, and failure or disarrangement at any one point holds up all future development. " June drop " of apples appears to fall into this catagory. For some reason as yet unknown fruit development which was initiated at blossom time fails to continue. Internal tree condition is undoubtedly the most important single factor in " June drop." From our present point of view it can be regarded as being due to the lack of the necessary growth substance and work along these lines is being planned as facilities and materials become available.

Another important point to notice is the distortion and cessation of growth produced by relatively high concentrations of 2-4 D. These symptoms may be confused with those due to certain virus diseases. Indeed, the appearance of some of these plants has misled trained pathologists. They invariably mislead practical growers. Plants which at one time suffered severely from an overdose of 2-4 D are still under observation, and it will be interesting to know how far they recover from the effects of such treatment. Unfortunately it has not been possible to carry out any transmission experiments. Investigators of virus diseases may find these observations important and they may

Fig. 1. Showing normal seeded (centre) and artificially produced seedless fruits. Note the completely filled fruits on left produced by N.O.A. and the larger partially hollow fruits produced by 2–4 D on the right.

Fig. 2. Showing a typical plant with fruit produced by spraying the emasculaed flowers with N.O.A. at 100 p.p.m.

Fig. 4. Showing a plant which had its flower trusses treated with 2–4 D at 100 p.p.m. Note the "Frenched" upper foliage and the elongated fruits of the upper truss.

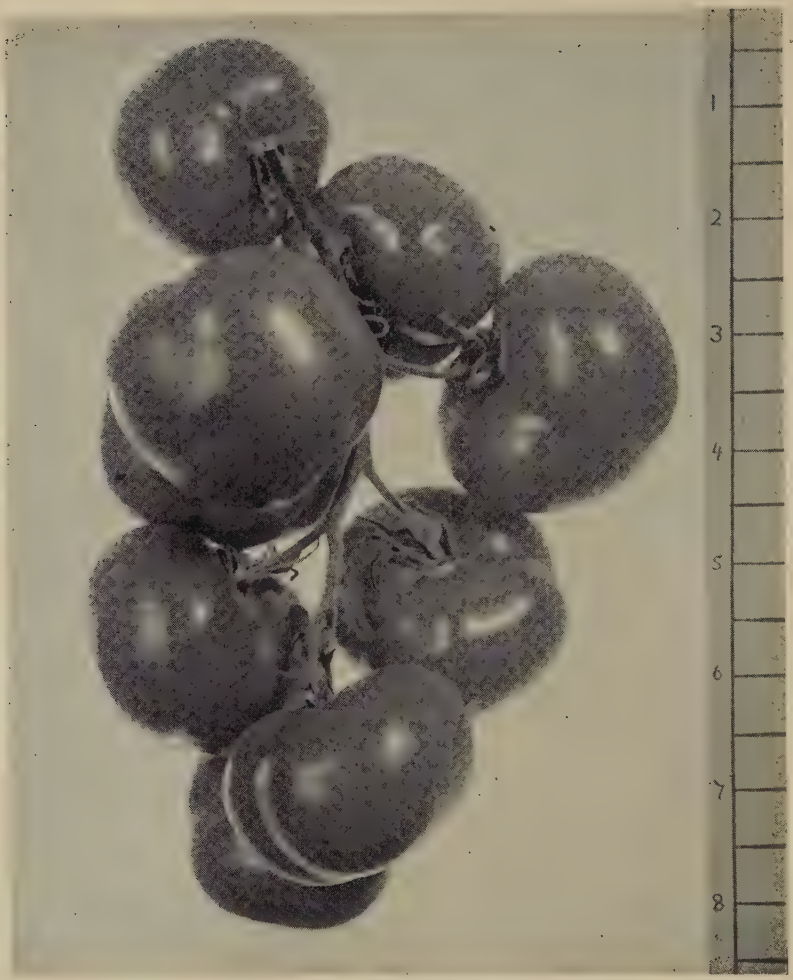

Fig. 3. Showing a typical truss of fruits produced by treating emasculated flowers with N.O.A. at 100 p.p.m., photographed January 8th, 1945.

Fig. 5. Showing a parthenocarpic fruit developing and bursting through the partially developed floral parts.

Fig. 6.
Right plant. Sprayed with N.O.A. 30 p.p.m. Note developing fruit but absence of epinasty.
Left plant. Control. Note no formative effects and no fruit development.

Fig. 7.

Showing right plant treated with 2–4 D at 5 p.p.m. (3 sprayings). Note Frenched foliage and peculiar shaped fruits. Left plant treated with 2–4 D at $2\frac{1}{2}$ p.p.m. plus N.O.A. at 15 p.p.m. Note recovery of leaves at top of plant and the peculiar enlarged convoluted fruits of the lower truss.

provide them with another line of attack upon this complicated problem. They are certainly a marked feature of these trials.

This is not the place to discuss the various theories of hormones and their activity. The present work brings out certain suggestions which are put forward at this time. These substances have specific effects in plant growth and development. Whether these substances produce their effect by combining with other substances so as to remove them, or whether they are the foundation upon which other substances are built, is not clear. There is a strong suggestion, as in the work of Thomas and Drew (5) that these substances may work in combination, that is a particular substance will only show its effect when present along with another substance. In this respect they are akin to enzyme systems, which are well known as important controllers of metabolism. Virus diseases are thought to be caused by the presence of self-propagating substances of a protein nature. It is suggested that investigations now being carried out on vitamins, virus diseases and enzyme systems, may at any time furnish us with an understanding of the present observations in the field of plant growth substances.

Summary and Conclusions.

1. Experiments were carried out during the summer and winter of 1944-45 using synthetic chemical substances as a means of inducing fruit development in the tomato.

2. Alpha-naphthalene-acetic acid, which is effective for the prevention of pre-harvest drop and the rooting of cuttings, failed to induce the development of parthenocarpic tomato fruits. The fruits set but did not develop beyond the size of walnuts.

3. Beta-naphthoxy-acetic acid at 30 p.p.m. and 2-4 dichlorophenoxy-acetic acid at concentrations as low at 1 p.p.m., both proved effective in inducing the development of fruits from emasculated tomato flowers.

4. Fruit development was stimulated by both these substances after a delay of upwards of three weeks between emasculation and the application of the growth substances to the ovarian tissues.

5. 2-4 D has proved much more effective than N.O.A. in the production of parthenocarpic fruits. Good set and development have been obtained with 2-4 D at 1 part in 5 million, but owing to the effect of certain unknown factors a concentration of 1-2 p.p.m. is advised.

6. In addition to inducing the set and development of emasculated flowers, 2-4 D has shown marked malformative influences. When used at a high concentration (100 p.p.m.) on the flower trusses, or at 10 p.p.m. sprayed over the plant as a whole, subsequent growth and development of the plant may be arrested, and it shows symptoms suggestive of virus disease. Plants still under observation show that, after a period, subsequent growth may be normal. This effect detracts seriously from the value of 2-4 D as a substance for use in commercial practice.

7. N.O.A. cannot be relied upon to induce fruit set of emasculated flowers at less than 30 p.p.m., and even higher concentration may be beneficial. N.O.A. has shown no distortion effects at concentrations up to 50 p.p.m.

8. It has been established that the best time to apply the growth promoting substance is within a few days of full bloom. Repeated trials have shown that on well-grown plants fruit development may be started from flowers which have been emasculated and allowed to remain in this condition for upwards of three weeks. Under favourable greenhouse conditions develop-

ment is noticeable within 48 hours of an application in the case of 2-4 D and 5 days with N.O.A.

9. Chemical analysis has failed to detect significant differences between normal pollinated and artificially produced fruits in sugar, acidity or vitamin C content.

10. The palate, however, was able to distinguish between the fruits produced by these two compounds. The ones produced by N.O.A. were almost normal in flavour, texture, etc., but these from 2-4 D were insipid, rather sweet, mild in flavour with a loose mealy flesh texture. Fruits produced by N.O.A. were practically normal in shape and were always filled with mucilage, whereas fruits produced by 2-4 D were always somewhat elongated, beaked, and were frequently partially hollow.

11. A practical solution of the non-setting of early and late greenhouse grown tomatoes is in sight.

12. Methods of application and technique in general is important. The setting of whole trusses at one time places a severe strain upon the plant as a whole, and modifications in culture may be necessary in order to keep the plants sufficiently vigorous.

13. The work in progress indicates that in nature a succession of growth substances may be involved in the production of mature fruit from the primary ovarian tissues. June drop of apples may ultimately be eliminated by a further development and application of our expanding knowledge of plant growth regulators.

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THE USE OF INDOLE-BUTYRIC ACID AND ALPHA-NAPHTHALENE-ACETIC ACID TO FACILITATE THE ROOTING OF YELLOW PERSHORE PLUM STOCKS.

By T. SWARBRICK.

The usual commercial method of raising the Yellow Pershore Plum is to dig up the suckers which arise from the roots of mature trees. Many of these stocks when dug are almost devoid of lateral roots, and in dry years may fail to become established in the nursery row.

Recent developments in the use of certain chemicals to facilitate the rooting of cuttings, and the acute shortage of rootstocks suggested the present trial which was carried out on a fruit farm in the Vale of Evesham under commercial conditions.

Materials and Methods.

About 2,000 Yellow Egg Plum suckers had been collected during the winter of 1943–44. Many of these had made strong growth but were devoid

of roots except for the small " heel " of old root. Many had no fibrous roots at all. These stocks were divided into two grades, 1st grade comprising stocks of two feet or more, 2nd grade those less than two feet long. Each group was then divided into three parts to which the following treatments were applied : 1, Control ; 2, Indole-butyric acid ; 3, Alpha-naphthalene-acetic acid.

The dipping material was prepared by making six gallons of a 20 p.p.m. concentration of indole-butyric and alpha-naphthalene-acetic acid respectively. This solution was then used to prepare a " cream " or puddle from the local clay, using a large zinc bath as the receptacle. The puddle was made so that when the stocks were dipped in it they would retain a liberal coating. The stocks were tied up into bundles which were dipped in the bath. The bundles were then heeled in the ground to await transplanting. The stocks were lined out at one foot apart in rows three feet apart. Dipping was carried out on 9th March, 1944, and the stocks planted out during the following 7 days.

Results.

A careful count was made on 30th June, 1944. The weather was unusually dry during the early part of the summer.

TABLE I.

Showing the Effect of Treatment upon the Stand of Yellow Egg Plum Stocks.

	Control	Indole-butyric acid	Alpha-naphthalene-acetic acid
Number Planted ..	873	894	1135
Number Dead ..	369	192	288
Number Living ..	504	702	847
% Living	58	79	74

The data given in Table I shows that a marked improvement in stand was obtained by the treatments. There is no significant difference between the results obtained by these two substances.

A general examination of these stocks made in early autumn showed quite clearly that those treated with indole-butyric acid had made much better leader growth than either the controls or those treated with alpha-naphthalene-acetic acid. In fact the control trees had produced very few good leader shoots, their growth being confined almost entirely to numerous short laterals.

General Conclusions.

Beneficial results were obtained from treating commercial Yellow Egg Plum rootstocks with either indole-butyric or alpha-naphthalene-acetic acids. The method of treatment was simple, and consisted of dipping the stocks in a clay puddle containing the growth promoting substance. This method is likely to be more certain and uniform in its results than the old-fashioned one of burying the stocks in a compost of well rotted farmyard manure for a short period prior to planting.

The benefits obtained were not confined to an increase in the stand of living stocks. Indole-butyric acid not only improved the stand of stocks ; it also gave a marked improvement in the growth of " leader " shoots. This was in marked contrast to the control stocks where the new shoot growth was confined to numerous short laterals.

EXPERIMENTS IN MINERAL NUTRITION.—II. THE VISUAL SYMPTOMS OF MINERAL DEFICIENCIES IN CROP PLANTS GROWN IN SAND CULTURES. PROGRESS REPORT, 1944.

By E. J. HEWITT.

The work described in this report is in continuation of the programme commenced in 1943 (1). Twenty-eight crops were grown in controlled nutrient sand cultures. The rain-water and distilled water techniques were again used as in 1943 with certain modification and improvements described below.

A. Rain Water Series.

Materials and Methods.

The pots were treated as described in the first report ; the sand was similar to that used previously ; for iron and boron deficiency it was washed (see under B. Distilled Water Series). An analysis of the sand showed :—

Fe 240 ppm. Mn 2·5 ppm. B 0·6 ppm. Ca not detected.

The rain-water (sampled in June and October) was analysed as follows :—

June sample : K ND. ; Mg 0·05 ; Ca 0·1 ; B 0·006 ; Fe 0·07 ; Mn 0·023 ; Cu 0·01 ; Zn 0·21 ppm.

October sample : K 0·4 ; Mg 0·56 ; Ca 2·1 ; B 0·03 ; Fe 0·08 ; Mn 0·C01 ; Zn 0·35 ppm.

pH (June) 5·4 ; (October) 6·8.

Separate tanks were provided for the rain-water used for watering iron and boron deficiency cultures.

Nutrient Solutions.

The nutrient solutions were made up as previously (1) except that ferric citrate was substituted for ferric chloride and the iron supplied at 5 p.p.m. The ferric citrate stock solution was kept free from infection by fungi by suspending a small amount of ethyl mercuric chloride in a 200 mesh phosphor-bronze gauze bag above the surface of the solution and also incorporating copper sulphate to supply copper at 0·03 p.p.m. in each application of nutrient solution, thus replacing the copper in the weekly supplementary trace elements solution, except in the iron deficient cultures, where extra copper was supplied at 0·1 p.p.m. Leaching was performed once a month.

The pH of the leachates varied between 6·3 and 7·5 except for the nitrogen deficient red clover which was 3·90, an unusually low value.

The pH values of the nutrients as applied (Table I) were raised by using the ferric citrate, in addition to avoiding the precipitation of ferric phosphate.

Owing to the discovery of appreciable quantities of ferric iron in the principal nutrients, iron deficiency solutions were made up later in the season as for manganese deficiency in the distilled water series.

At sowing most cultures were given 2 litres of complete nutrient but omitting trace elements ; the Fe and Ca deficient cultures received only their respective solutions, cereals were germinated with rain-water followed by the respective deficiency solutions and garden beet was given the appropriate deficiency nutrients from the start ; Lucerne was inoculated before sowing in all cultures.

TABLE I.

pH Values of Nutrient Solutions (ready for application).

Complete Nutrient	5·43	Omitting Ca	5·03
„ „ with twice phosphate level of above.	5·48	„ Mg	4·78
Omitting N	5·07	„ B	4·93
„ K	5·05	„ Fe	5·10
„ P	5·36	Rainwater	5·44

Seeds were sown direct in sand for calcium and minor element deficiencies and in sand or compost and transplanted in the case of the remainder. Sowings were made about 10 days later than the corresponding dates in 1943. Barley was sown in December and thereby escaped serious mildew attack.

Routine spraying approximately every 10 days during July and August was carried out with 0·05% nicotine solution and standard strength " Bouisol " (1 fl. oz. per 5 galls.) on the brassicae, and " Microsul " on the clovers. Damage due to aphis and fungus pests was generally slight except on swedes and turnips where aphis damage was severe. No signs of nicotine damage were observed this season. Sulphonated lorol and methyl cellulose were again used as wetters.

TABLE II.

Crops Grown and Treatments Given.

Crop and Variety.	Nutrient Elements Omitted.
Wheat .. .. Red Marvel	N, K, P, Mg
Barley .. .. Plumage Archer	N, K, P, Ca, Mg, Fe
Oats .. .. .. White Star	N, K, P, Mg
Rye .. .. .. (Winter Var.)	K, Mg
Cabbage .. .. Improved Winningstadt ..	Ca, Fe
Cauliflower .. .. Majestic	Ca
Rape .. .. Black	B
Marrow Stem Kale .. Green	Ca, Mg, Fe
Hungry Gap Kale ..	B, B with $CaCo_3$ added
Turnip .. .. Early White Stone	Ca
Swede .. .. .. Purple Top	Ca, Mg
Carrot .. .. Early Model	N, K, P, Ca, Mg, B
Parsnip .. .. Syston Intermediate ..	N, K, P, Ca, Mg
Celery .. .. .. Monarch White	B
Mangold .. .. Golden Globe	B
Seakale Beet ..	Ca, Mg, B, B with $CaCo_3$ added
Garden Beet .. .. Detroit Improved Globe ..	Mg, B, B with $CaCo_3$ added
Broad Bean .. .. Exhibition Longpod ..	Ca, B
Dwarf Bean .. .. Masterpiece	N, K, P, Ca, Mg
Runner Bean .. Scarlet Emperor	N, K, P, Ca, Mg
Pea .. .. .. Duplex	N, K, P, Ca, Mg
Red Clover .. .. 1944 Dorset Marlgrass ..	N, K, P, Ca, Mg, Fe, B, B with $CaCo_3$ added
Red Clover .. .. 1943 Dorset Marlgrass ..	N, K, P, Ca, Mg
White Clover .. Alsike	N, K, P, Ca, Mg
Lucerne	N, K, P, Ca, Mg
Flax .. .. .. Liral Prince	Ca
Tomato .. .. Early Market	K, Ca, Mg, Fe, Trace Elements
Potato .. .. Majestic	N, K, P, Ca, Mg, Fe
*Hops .. .. Fuggle	N, K, P, Ca, Mg, Trace Elements, and a series in greenhouse compost

* In conjunction with Hop Disease Investigation Scheme of the Agricultural Research Council.

Description of Typical Symptoms.

Observations confirming previously tentative records are followed by (C) while tentative records are followed by (T). The times listed are those required to produce typical symptoms.

Wheat.

Omissions.

Nitrogen .. .. (3 weeks) — Growth thin, dwarfed; no tillering; leaves small, erect, pale, yellow green, yellowing and withering tips; primary roots extensive, secondary poor; head formation late and greatly reduced.

Potassium .. .. (8 weeks) — Growth bushy, dwarfed; tillering increased; older leaves pale brown lesions, severe scorching from tips; secondary roots extensive; head formation delayed.

Phosphorus .. .. (5 weeks) — Growth thin, dwarfed; no tillering; leaves small, erect, dull green, yellowing at tips with faint bluish-purple tints towards base; primary roots extensive, secondary poor; head formation very late and greatly reduced.

Magnesium .. .. (8 weeks) — Growth reduced; leaves pale, orange-yellow intervenal striping, yellowing and scorching of tips; rooting normal; head formation reduced.

Barley.

Omissions.

Nitrogen .. .. (4 weeks) — Growth thin, dwarfed; no tillering; leaves small, erect, pale, yellow-green, tips withering; stems red at base; head formation late and greatly reduced.

Potassium .. .. (6 weeks) — Growth bushy, dwarfed, tillering excessive and often nearly horizontal; older leaves grey-green lesions becoming white followed by severe tip and marginal scorching; head formation late and reduced.

Phosphorus .. .. (5 weeks) — Growth thin and dwarfed; no tillering; old leaves small, erect, dull blue green, purpling of margins and main veins near base, then generally, tips withering; younger leaves olive-green with purple veins; stem bases purple; head formation greatly delayed and reduced; awns purple tints.

Calcium .. .. — No symptoms observed.

Magnesium .. .. (8 weeks) — Slightly dwarfed; old leaves paling, becoming deep yellow at tips and along margins, with intervenal orange to buff striping and dark brown marginal necrosis; head formation slightly reduced.

Oats.

Omissions.

Nitrogen .. .. (4 weeks) — Growth thin, dwarfed; no tillering; leaves erect, small, pale, old leaves pale intervenal lesions, red-brown tints towards tip becoming scorched; head formation greatly reduced and delayed.

Potassium .. .. (6 weeks) — Growth dwarfed; tillering increased; older leaves orange tints, green blotches near tips, finally severe red-brown scorch; head formation reduced.

Phosphorus .. .. (4 weeks) — Growth thin and dwarfed; no tillering; leaves small, purpling at extreme tips and finally scorching red-brown; stem purpling; head formation greatly reduced and delayed.

Magnesium .. .. (8 weeks) (T) — Leaves pale, broad pale green intervenal striping, older leaves intervenal and marginal red or orange tints.

Rye.

Omissions.

Potassium .. .. (T.) — Growth bushy; leaves limp, pale, with grey intervenal lesions becoming white, tips yellowing, finally scorching.

Magnesium .. .. — No symptoms observed.

Cabbage.

Omissions.

Calcium .. .. (T.) — Young leaves orange margins followed by grey-brown scorching and necrotic spotting.

Cauliflower.

Omissions.

Calcium .. .. (T.) — Older leaves marginal orange or reddish tints as in Boron deficiency; later middle leaves intervenal grey-brown necrosis, margins remaining green or yellow-green.

Rape.

Omissions.	
Boron .. .. (14 weeks) (T.)	Lateral growing points die out; young leaves distorted; old leaves purple marginal tints; petioles twisted with transverse corky roughening in rings near base.

Marrow Stem Kale.

Omissions.	
Calcium .. .. (11 weeks) (T.)	Older leaves, margins pale green, purpling near base, centres orange intervenal tints with extensive fine grey necrotic spotting; young leaves yellow-green mottling commencing at margins, becoming completely white.
Magnesium .. .. (9 weeks)	Older leaves marginal and intervenal marbled chlorosis followed by orange and pink tints and pale brown necrotic areas.
Iron .. .. (T.)	Young leaves paling then intervenal yellow-green mottling, recovering later in season.

Hungry Gap Kale.

Omissions.	
Boron .. .. (12 weeks)	Growing points die out, regeneration in axils; young leaves defective laminae; old leaves yellow, orange and purple marginal tints; petioles brittle, curled, with corky roughening and splitting round base, stems corky; pith with brown water-soaked breakdown in centre.

Turnip.

Omissions.	
Calcium	No symptoms observed. Growing points damaged by swede midge.

Swede.

Omissions.	
Calcium	Younger leaves fine mottling. Growing points damaged by swede midge.
Magnesium .. .. (9 weeks)	Old leaves marginal and intervenal yellow-green marbling, orange and red tints later.

Carrot.

Omissions.	
Nitrogen .. .. (7 weeks)	Growth very weak; leaves very small, pale yellow-green followed by red tints including petioles; roots very small.
Potassium .. .. (12 weeks)	Growth stunted bushy; younger leaves hard, short; old leaves dark green, margins yellowing followed by dark brown scorching from tips, finally wilting and collapse of leaf; roots slender.
Phosphorus .. .. (8 weeks)	Growth weak; leaves small, dull, dark blue-green, becoming purple, finally olive at tips and collapsing; petioles purpling; roots small.
Calcium	Leaves small and pale.
Magnesium .. .. (10 weeks)	Old leaves marginal yellowing becoming general chlorosis, followed by red tints.
Boron .. .. (20-26 weeks) (T.)	Young leaves stunted, laminae often defective; old leaves yellowing at margins; petioles brittle, twisted, lateral petioles short; roots split near crown, sometimes blackened in crown, internal brown water-soaked area below crown.

Parsnip.

Omissions.	
Nitrogen .. .. (6 weeks)	Growth very weak, leaves very small, pale yellow-green, petioles red or yellow; roots very small.
Potassium .. .. (10 weeks)	Old leaves, marginal and intervenal yellow-green followed by narrow marginal scorching and intervenal brown necrotic spots and areas.
Phosphorus .. .. (6 weeks)	Growth weak, leaves small, dark dull green with faint purple tints; petioles purple; roots small and spindly.
Calcium	Leaves pale.
Magnesium .. .. (8 weeks)	Old leaves broad marginal bright yellow tint sweeping boldly between major veins; faint pink tinting later.

Celery.

Omissions.	
Boron .. .. (3-4 weeks)	Growth bushy, growing points die out, axillary regeneration; leaves small, distorted, some intervenal yellowing; petioles very brittle, twisted and bent, considerable transverse splitting across vascular bundles, browning and curling back of tissues into rough hooks; 1 plant killed.

Mangold.

Omissions.	
Boron .. .. (14 weeks)	Growing points die out, producing multiple crowns; leaves dull, youngest bent at tips; petioles orange-brown with transverse black corky lesions upper surface near base; corky scales and splitting near crown.

Seakale Beet.

Omissions.	
Calcium .. .. (12-14 weeks)	Growing points blackened, die out; young leaves, death and scorching of margins just behind tip causing backward curling and beak-like appearance, succeeding leaves with less laminae, finally only blackened stunted midrib.
Magnesium .. .. (7 weeks)	Old leaves marginal and intervenal orange and yellow blotching followed by brown necrotic areas extending from margins.
Boron	Crinkling of laminae. No characteristic symptoms.

Garden Beet.

Omissions.	
Magnesium	Old leaves blotchy intervenal yellowing with pale red tints.
Boron .. .. (20 weeks)	Growing points die out, causing multiple crowns; young leaves narrow, strap-like, dark red or nearly black, petioles with transverse corky lesions; corky ribbing around crown of root and canker in surface at or below level of sand; black vascular necrotic regions within healthy tissue.

Broad Bean.

Omissions.	
Calcium	No symptoms.
Boron .. .. (15 weeks) (T)	Growing points die out; upper leaflets very erect as in P deficiency, orange-yellow tints with marginal and intervenal browning; rapidly defoliating from tip of leaf, youngest leaflets scorched black; upper flowers defective or not setting pods; roots thickened and stunted.

Germination of Seeds Harvested.

A considerable proportion of seeds harvested from both series of cultures described above germinated with twin or triple shoots indicating death or weakness of the primary growing point.

Dwarf (French) Beans.

Omissions.	
Nitrogen .. .. (6 weeks)	Growth weak at first, recovering in 10 weeks; leaves small, yellow-green, yellowing and falling prematurely; flowering reduced; pods small.
Potassium .. .. (7 weeks)	Growth stunted; old leaves convex, marginal and intervenal yellow-green, margins upcurled with brown spotting and irregular brown scorch; occasionally dispersed intervenal necrotic spotting expanding into scorched areas; crop reduced.
Phosphorus .. .. (7 weeks)	Growth weak, dwarfed; leaves small, dark dull green paling to olive green intervenally, yellowing withering and falling; crop greatly reduced; pods very small.
Calcium (T) ..	Pale, older leaves yellowing; pods yellowing and not filling.
Magnesium .. .. (7 weeks)	Growth reduced; old leaves intervenal paling with yellow and orange tints; purple spotting close to main veins and margins near base of leaf, becoming profuse bronze intervenal necrotic spotting; rapid defoliation.

Runner Bean.

Omissions.	
Nitrogen .. .. (6 weeks)	Growth at first weak, recovering after 9 weeks; leaves small pale yellow-green, then yellow with buff marginal scorch; veins and petioles red; flowers and crop reduced.
Potassium .. .. (8-9 weeks)	Growth reduced, old leaves convex with wide marginal chlorosis, some intervenal necrosis, severe inrolled pale brown marginal scorch; scorch extending to tip leaves; flowers and pods greatly reduced; plants killed.
Phosphorus .. .. (10 weeks)	Growth very thin, greatly reduced; leaves small, dark dull green, later olive-green and yellow with brown necrotic spots, finally grey and papery, severe defoliation, death of plants; flowers and pods very few and small.

Calcium (T)	Young leaves pale with some marginal white mottling and necrotic spotting near tips.
Magnesium (11 weeks)	Old leaves general paling with yellow-green intervenal mottling; marginal and intervenal profuse purple and bronze necrotic spotting expanding into bronzed scorched areas; veins red-brown; pods reduced.

Pea.

Omissions.

Nitrogen	Growth reduced, leaves small and yellowing from base; early maturity; pods small but well filled.
Potassium (9 weeks)	Growth dwarfed; internodes shortened; old leaves marginal and intervenal bleaching, margins upcurled and scorched, upper leaves dark green, cupped and fasciated at tips, finally scorching; maturity greatly delayed; pods very small, nearly empty.
Phosphorus (9 weeks)	Growth thin and spindly; leaves small, dull, pale olive, finally withering from base; pods few, poorly filled.
Calcium (T)	Tip leaflets folded up; yellow and withering; upper leaves pale yellow-green, marginal and intervenal bronze tints.
Magnesium (9 weeks)	Old leaves central intervenal chlorosis, margins green, brown necrotic areas developing intervenally, margins finally scorching; pods small but well filled.

Red Clover (1944 Sowing).

Omissions.

Nitrogen, Potassium, Phosphorus, Magnesium. Typical symptoms as recorded for 1943.

Calcium (T)	Complete chlorosis, some leaves on flowering stems; upper petioles and pedicels red-brown.
Boron (T.)	Yellowing and intervenal chlorosis tip leaves.
Iron (T.)	Upper leaves paling intervenally, finally completely yellow.

Red Clover (1943 Sowing).

Complete Nutrient	Normal, slightly darker than and not quite so vigorous as 1944 series.
Omitting Nitrogen	Growth thin, slightly pale, leaves small, occasional Mg deficiency symptoms.
Omitting Potassium	Dwarfed, many plants dead, typical symptoms hardly discernible, mainly bronzing or darkening of leaves and occasional blue-green intervenal ar as.
Omitting Phosphorus.	Growth extremely weak; many plants dead; leaves few, small typical olive-green with irregular dark brown spotting, withering; collapse of petioles; no flowering throughout season.
Omitting Calcium	Growth normal; occasional leaves marginal yellowing or browning and scorching; some Mg deficiency symptoms.
Omitting Magnesium.	Growth thin, several plants dead; typical symptoms prevalent but less general than in first year cultures.

Number of plants remaining out of original 30 in each treatment :—Complete 29; –N 15; –K 11; –P 20; –Ca 22; –Mg 16. Generally the typical deficiency symptoms are less evident in the second year except in phosphate deficiency.

Alsike Clover.

Omissions.

Nitrogen	Growth thin, pale, improving later.
Potassium (7 weeks)	Slightly stunted; profuse white and pale buff spotting near margins, marginal yellowing and scorching; spotting occasionally replaced by intervenal hatching; spots larger and fewer in fresh growth after cutting.
Phosphorus (5-6 weeks)	Growth very thin and weak; leaves very small, dark green, becoming dull olive, yellowing and finally scorching; petioles collapse and wither; flowering greatly reduced.
Calcium (15 weeks) (T.)	Young leaves marginal browning; pedicels wilting and shrivelling 1–2″ behind flowers (*Botrytis* present).
Magnesium (10 weeks)	Old leaves pale, intervenal yellow-green with orange and red tints; margins green or yellow becoming pink or bright red and scorching.

Lucerne.

Omissions.

Nitrogen	Growth initially thin, recovering later, leaves pale yellow.

Potassium .. .. (8 weeks)	Growth slightly stunted; older leaves profuse white spotting near margins towards tips, later marginal yellowing, pale brown scorching and occasionally central necrosis; spots much larger after cutting and coalescing into scorched areas.
Phosphorus .. .. (6 weeks)	Growth very thin and weak, leaves small dark green or blue-green, becoming pale olive-green and scorching; irregular dark brown spotting rare; flowering and seed greatly reduced.
Calcium .. .. (T.)	Younger leaves some marginal and intervenal yellowing towards base, followed by irregular marginal necrosis with red-brown tints around necrotic areas.
Magnesium .. .. (6-7 weeks)	Old leaves central intervenal yellowing, margins remaining green; later general intervenal orange-yellow tinting commencing from margins, reddish tints on underside; finally irregular intervenal central and marginal necrosis with red tints bordering necrotic areas.
Boron (T.) .. .. (26 weeks)	Yellowing of young leaves.

Flax.

Omissions.	
Calcium .. .. (6-7 weeks) (C.)	Growing points killed, shoots fasciated; young leaves yellowing with tip die-back; profuse lateral and floral branching; pedicels yellowing, wilting and collapsing; flower buds yellow and distorted or blind.

Tomato.

Omissions.	
Potassium (6 weeks)	1943 symptoms reproduced.
Calcium .. .. (10-12 weeks) (C.)	Growing point yellowing and dying; upper expanded leaves purpling tips and margins, yellowing with orange tint towards base and centre, finally yellowing and collapsing from tip; tip die-back of upper trusses, failure to set fruit at distal end; fruit formed good quality, free from "green-back."
Magnesium .. .. (7 weeks)	1943 symptoms reproduced. Fruit, hard yellow type of "green-back" general, more pronounced than in cultures receiving complete nutrient.
Iron .. .. (20 weeks)	Tip leaves pale yellow-green, central intervenal ivory chlorotic mottling commencing from base of compound leaf and leaflets; pale brown large necrotic spots close to veins at tip of leaf; young expanded leaves marginal and intervenal scorching; young petioles slight purpling.
Trace Elements (*Boron*)	Upper expanding leaves stunted, yellowing at base, red and purple tinting of veins and scorching of margins, side petioles very brittle and collapsing.

Potato.

Omissions.	
Nitrogen, Potassium, Phosphorus, Magnesium.	Symptoms reproduced as observed in 1943.
Calcium .. .. (8-10 weeks) (T.)	Growth bushy; youngest leaflets tend to fold forwards, yellowing at base and margins, death and blackening of leaf tip with reflexing, brown necrotic pin-holes near base of leaflet, distorted and wavy margins; tubers extremely numerous, small, malformed and budding profusely, with brown water-soaked and split areas in distal region; brown necrosis of vascular ring visible on cutting upon; small tubers formed above sand up to 5th node.
Iron	Tip leaves intervenal yellowing; brown spotting and scorching of lower leaves, resembling potassium deficiency (confirmed in tissue test).

Hop.

Low Nitrogen ..	Growth very thin, leaves small, pale, becoming yellow and defoliating, petioles red, very few laterals and flowering greatly reduced.
Omitting Potassium..	Growth stunted; leaves small, lower leaves intervenal paling followed by severe brown, grey or purple-tinted upcurled marginal scorch extending only slightly between veins, narrow yellow-green chlorotic area within scorched margins; leaves finally shrivelling with considerable defoliation; laterals and flowering poor.
Low Phosphorus ..	Growth thin, leaves small, dull olive green becoming bronze due to profuse brown spotting intervenally on underside of leaf, finally yellowing and defoliating; laterals and flowering reduced.
Omitting Calcium ..	Growth reduced, generally slightly yellow-green intervenally becoming pale buff and defoliating extensively from base; some bronze spotting as in P deficiency, laterals and floral spikes frequently dying back and generally reduced.

Omitting Magnesium Growth reduced, lower leaves pronounced intervenal yellow-green to yellow-chlorosis followed by fine brown necrotic spotting inside margins and intervenal areas, finally leaves orange-yellow with extensive brown intervenal necrotic areas and occasional marginal scorching, severe and extensive defoliation, laterals and flowering much reduced.

Omitting Trace Elements. Growth reduced, lacking vigour, leaves small, pale, older leaves slightly yellow-green intervenally, considerable intervenal bronze spotting under surface (as in Low P.) some browning and scorching intervenally towards base of leaf, and withering.

Compost .. .. Growth lacking vigour, leaves small pale, often yellow or nearly white, considerable defoliation, laterals very numerous but frequently wilted or dead at growing point; flowering greatly reduced (Low Nitrogen appearance).

B. Distilled Water Series.

Materials and Methods.

Pots were treated exactly as in 1943. The sand was however washed in order to remove iron (the principal impurity), manganese and boron. The method adopted consisted in first saturating about 40 lb. of 20-30 mesh sifted sand with 7-10% HCl, allowing a slight excess of liquid and then blowing in steam at 10-15 lb. per sq. in. from a glass jet, thus heating and agitating the sand-acid mixture, until the sand appeared silver-grey on rinsing. The sand was rinsed with distilled water until the rinsing water gave a green reaction with bromocresol green.

The nutrient solutions used for the manganese deficient cultures were purified as for 1943 (2), but in more concentrated form. Some trouble was experienced with the magnesium sulphate which repeatedly produced algal growth after purification, suggesting that a trace of manganese still remained, but the quantity of iron as determined by the thiocyanate-allyl alcohol method using the Spekker absorptiometer was not different from the blank after purification by the adsorption technique.

The ferric citrate was prepared from Analar citric acid and ferric hydroxide prepared from Analar ferric alum as described previously (1).

In spite of the use of washed sand, iron deficiency cultures were not entirely successful, and appreciable amounts of iron were detected in the nutrient salts, principally in the calcium nitrate, and sodium phosphate.

The solutions used for the boron deficient cultures were similar to those of 1943. As the results did not fulfil expectations, a survey of the boron content of the separate solid nutrient salts was made at the end of the season, using the methyl alcohol esterfication method in conjunction with the quinalizarin reaction. (Details of the method used and its adaptation to the removal of boron from nutrient salts will be published later.) The following results were obtained :—

Solid Compound. B in p.p.m. $MgSO_4 7H_2O$ AR : 9·0. KNO_3 AR : 4·8. $Ca(NO_3)_2$ Anhyd : 3·8. $Na.H_2PO_4$ $2H_2O$: 0·5. $Ca(NO_3)_2$ prepared from re-distilled HNO_3 and " Fluorine free " $CaCO_3$: 0·5.

A hot water extract of broken unwaxed pottery gave a strong positive reaction for boron as well as potassium calcium and magnesium but negative for iron and manganese. It was estimated that up to 0·01 p.p.m. B was being supplied as an impurity in each application of nutrient solution.

Crops and Treatments.

The crops grown and treatments given are set out in Table III.

TABLE III.

CROPS GROWN AND DEFICIENCY TREATMENTS.

Crop and Variety.		Nutrient Elements Omitted.
Cauliflower	Majestic	B
Marrowstem Kale ..	Green	Mn
Swede	Purple Top	Mn
Parsnip	Syston Intermediate ..	Fe, Mn, B
Broad Bean	Exhibition Longpod ..	Mn, B
Dwarf Bean	Masterpiece	Mn
Runner Bean	Scarlet Emperor ..	Mn
Pea	Duplex	Mn
Red Clover	Dorset Marlgrass ..	B
Lucerne		B
Flax	Liral Prince	Fe, Mn, B
Tomato	Market King	Fe, Mn, Fe and Mn, B
Potato	Majestic	Fe, Mn, B

Sowings were made as described previously. Tomato plants were selected from a batch sown on March 18th. The first sowing of parsnips gave almost no germination, so the parsnips were re-sown relatively late in the season.

Cauliflower.

Omitting Boron (4 weeks) .. Growth checked soon after transplanting, growing point died out, leaves small, narrow, thick, leathery, fasciated, dark green with purple tinting particularly underside, older leaves marginal orange and purple tinting; axillary and adventitious shoots regerenated subsequently. A second specimen showed milder early symptoms and later developed typical symptoms observed in 1943.

Marrowstem Kale.

Omitting Manganese (6-8 weeks) Growth reduced, older leaves marginal and intervenal yellow-green mottling becoming dull grey-green and finally white.

Swede.

Omitting Manganese Leaves initially yellow-green marginal and intervenal mottling, disappearing after 12-14 weeks.

Parsnip.

Omitting Iron (8-10 weeks) .. Leaves small, young leaves pale, bright yellow-green intervenal motting.

Omitting Manganese (4 weeks) Growth stunted, greatly reduced; old leaves dark green, dull yellow chlorosis diffusely between major veins, scattered necrotic spotting; roots small.

Omitting Boron .. No typical symptoms.

Broad Bean.

Omitting Manganese (10 weeks) Growth reduced, old leaves faint diffuse intervenal yellow-green; pods few, upper ones frequently blackened after setting; beans developed symptoms resembling "Marsh Spot" in peas (3); accentuation of depression between cotyledons, browning of margins, developing into pithy brown discoloured hollow 8-10 mm. by 3-4 mm. pithy tissue 1-2 mm. deep; browning of plumule and leaf primondia in embryo, external appearance normal.

Omitting Boron (11 weeks) .. Growth stunted, growing points die out; young leaflets erect (as in P deficiency) orange-yellow tints with scorching from tips, defoliating rapidly from tip of leaf, roots blackened, stunted, nodules almost absent, death of upper flowers without setting, pods few and blackening early.

Dwarf Bean.

Omitting Manganese (6-8 weeks) Growth reduced and stunted, leaves small, old leaves pale, yellow-green intervenal mottling, severe brown necrotic spotting, particularly near margins, leaves shrivelling; pods frequently yellow and unfilled; beans normal.

Runner Bean.

Omitting Manganese (10-14 weeks) — Growth reduced, leaves small, pale, old leaves yellowing (similar to Low N) intervenal yellow mottled areas centre of leaf (late in season) followed by brown necrotic areas including veins; pods set frequently yellow and unfilled; beans developed symptoms resembling "Marsh Spot" in peas (3); brown depression inner surface cotyledons. 12-14 mm. by 3-5 mm. with brown margin, frequently browning of growing point, plumule and leaf primordia of embryo; external appearance normal.

Pea.

Omitting Manganese (10 weeks) — Growth reduced, leaves small, pale intervenally, occasional brown necrotic spotting and marginal scorching; pods few, poorly filled; typical "Marsh Spot" developed, occasionally producing grey water-soaked appearance visible outer surface cotyledons, more severe in pods set late and left to dry on plants.

Red Clover.

Omitting Boron (3-4 weeks) .. Early growth of seedlings slow, growing points die out, leaves rudimentary, not expanding, stiff and thick, yellowing with red tints around margins; petioles very stunted, tendency to curl down to sand; roots brown, stunted and thickened, death of majority, a few recovering and continuing normal growth from axillary shoots.

Lucerne.

Omitting Boron (3-4 weeks) .. Seedling growth very slow, growing points die out, leaves rudimentary, not expanding, stiff and thick, dark green with red marginal tints, becoming yellow; petioles stunted and reflexed, roots brown and stunted. Seedlings finally die out except two which recovered after 9 weeks and made normal growth for 20 weeks, later developing mild chlorosis of young leaves. A fresh sowing produced no symptoms for 20 weeks when apical growth ceased, leaves remained small, numerous axillary chlorotic shoots developed at sand level without elongating.

Flax.

Omitting Iron (6-7 wks) (C.) .. Young leaves and shoot tips chlorotic, leaves paling from basal region.

Omitting Manganese (8 weeks) (C.) — Growth slow, very stunted, leaves small pale, crowns leaves often yellow, lower leaves yellow or white necrotic areas and orange tints scorching margins and tips; floral branches unusually short and stiff, fruiting reduced, ripening delayed.

Omitting Boron (10 weeks) .. Growth thin, stunted, primary and lateral growing points die out; leaves narrow, pale, tips scorched and margins distorted, shoots small, chlorotic, frequently wilting and browning; floral branches slender, flower buds blind or distorted, fruiting reduced.

Tomato.

Omitting Iron .. As for rainwater series but milder.

Omitting Manganese (3-5 weeks (C.) — Additional symptoms; young leaflets tend to curl up and scorch at margins, necrotic spotting close to veins, upper trusses reduced, flowers falling prematurely.

Omitting Iron and Manganese (T.) — Initially showed Mn deficiency symptoms after 3 weeks, followed by recovery for 4 weeks then reappearing in mild form; after another 4 weeks tip leaflets paling yellow-green at base of leaf, becoming generally yellow or mottled, yellow-green petioles and mid-rib purplish. Non-typical Mn type of symptoms reappearing after further 8 weeks, leaves green towards base and very chlorotic at tips.

Omitting Boron (C.) .. Additional symptoms; growing points yellow and bent to side, dying out; axillary ones developed similarly; upper trusses shrivelling, fruit small; seeds with blackening of outer cells.

Potato.

Omitting Iron (12-14 weeks) .. Tip leaflets pale, yellow intervenal mottling commencing at base of leaflets; potash type spotting and scorching lower leaves, tissue test indicating low K status (Table IV).

Omitting Manganese (9 weeks) — Growth stunted, young leaves and side shoots small, black spots close to midrib near base enlarging with shiny grey borders and coalescing; young basal leaflets margins scorching and incurling, finally withering completely; early death of haulms; tubers small.

Omitting Boron .. Young leaflets slight marginal and intervenal paling at base, mild K deficiency symptoms on lower leaves (see Table IV); tubers normal.

TABLE IV.

Tissue Test for Potassium on Potato Petioles.

Rainwater Series.			Distilled Water Series.			
Treatment.	Complete.	—Iron.	Complete.	—Iron.	—Manganese.	—Boron.
Assessment	Med	Low	Med	Low	Med	Low

Summary.

1. The survey of visual symptoms of mineral deficiencies was continued with 28 crops grown in controlled nutrient deficiency sand cultures.

2. The technique for studying trace element deficiencies of crops grown on a large scale was extended by the development of a method for obtaining washed sand in large quantities, using steam and 7-10% HCl.

3. With the rain-water and distilled water technique the following deficiency symptoms were observed :—

Nitrogen, Phosphorus, Potassium, Magnesium in Barley, Carrot, Parnsip, Dwarf Bean, Runner Bean, Pea, Red Clover, Alsike, Lucerne, Potato.

Nitrogen, Phosphorus, Potassium in Wheat, Oats. Potassium in Rye, Tomato.

Calcium in Cabbage, Cauliflower, Marrowstem Kale, Sea Kale, Beet, Pea, Alsike Clover, Flax, Tomato, Potato.

Magnesium in Marrowstem Kale, Swede, Sea Kale, Beet, Garden Beet, Tomato.

Iron in Marrowstem Kale, Parsnip, Red Clover, Flax, Tomato, Potato.

Manganese in Marrowstem Kale, Parsnip, Broad Bean, Dwarf Bean, Runner Bean, Pea, Flax, Tomato, Potato ; symptoms resembling " Marsh Spot " were observed in Broad and Runner Beans.

Boron in Cauliflower, Rape, Hungry Gap Kale, Carrot, Celery, Mangold, Garden Beet, Broad Bean, Red Clover, Lucerne, Flax, Tomato.

4. Most nutrient salts contained sufficient boron and iron to prevent the production of severe deficiency symptoms in some crops. Considerable amounts of boron and calcium and some potassium and magnesium could also be leached from the pottery.

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EXPERIMENTS ON THE CONTROL OF MAGNESIUM DEFICIENCY IN GLASSHOUSE TOMATOES.

PROGRESS REPORT II.

By J. O. JONES, D. J. D. NICHOLAS, T. WALLACE, and A. JEFFERISS.*

Experiments on the control of magnesium deficiency in glasshouse tomatoes were continued in 1944. Trials were carried out at Centres I, II and III, described in Progress Report I (1), and also at two other centres where magnesium deficiency has been a very serious problem.

The experimental treatments at the first two centres consisted of base dressings at 6 cwt. per acre of magnesium sulphate (30% MgO)† and at Centre III, in addition, a further experiment was carried out to compare the effect of different rates of soil applications of magnesium sulphate as base dressings and of foliage spray treatments using a $2\frac{1}{2}\%$ solution of this compound at intervals during the season. At Centre IV soil treatments were compared with spraying in one house and in two other houses spray treatments alone were tested. At Centre V only spraying experiments were carried out.

The results have shown that a soil dressing at 10 cwt. per acre magnesium sulphate, used as a base dressing, is required to effect a satisfactory control of the deficiency in severe instances, whilst a similar or even more effective control can be obtained by a spraying technique using only $1\frac{1}{2}$ cwt. per acre of this material.

Centre I.

The house at this centre was divided into 4 plots which received the following treatments in the form of a base fertiliser:—Plot 1, N.P.Mg.; Plot 2, N.P.; Plot 3, N.P.K.Mg.; Plot 4, N.P.K.

The magnesium sulphate was applied at the rate of 6 cwt. per acre with the base dressings on 24/2/44 and the house planted with the variety E.S.1 during the following week. In addition to the above treatment the whole house had been given a heavy dressing of well-made straw compost.

Results.

Observational Data.

On inspecting the house on 22/3/44 it was observed that all the plants were suffering from nitrogen deficiency due to the compost dressing, but by 20/4/44, after two or three soil applications of sulphate of ammonia, applied in solution, the plants were of normal appearance and had made good growth.

Observations for three dates are summarised below.

Severity of Magnesium Deficiency Symptoms.

Date	Plot 1	Plot 2	Plot 3	Plot 4
20/4/44	Nil	Nil	Nil	Nil
19/5/44	Slight	Slight-Medium	Slight	Slight-Medium
26/6/44	Slight	Medium	Slight-Medium	Medium

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† In all experiments described herein the form of magnesium sulphate used was calcined kieserite ($MgSO_4 . 1H_2O$) containing 30% MgO.

It is evident from the observational data that the addition of magnesium sulphate considerably reduced the foliar symptoms of magnesium deficiency. The addition of potash to plots 3 and 4 produced no clear effect on the severity of the visual symptoms in these two plots.

Chemical Data.

TABLE I.

			As % Ash.				% Dry Matter.			
Date.	Plots & Treatment.	Ash as % D.M.	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
20/4/44	1. Mg	22·15	32·85	1·85	19·73	4·35	7·27	0·41	4·37	0·96
	2. Nil	22·27	30·09	1·75	20·43	3·90	6·70	0·38	4·55	0·87
	3. Mg & K	22·84	30·03	1·80	20·75	3·79	6·86	0·41	4·74	0·87
	4. K	22·58	29·51	1·80	21·12	4·72	6·66	0·40	4·77	1·07
19/5/44	1. Mg	30·33	35·04	1·20	18·93	3·04	10·62	0·36	5·74	0·92
	2. Nil	28·64	34·66	1·10	19·76	3·03	9·92	0·31	5·66	0·87
	3. Mg & K	32·92	32·52	0·82	20·12	2·65	10·70	0·27	6·62	0·87
	4. K	30·61	33·00	0·81	21·56	2·75	10·10	0·25	6·60	0·84
26/6/44	1. Mg	32·55	33·95	0·94	19·17	2·26	11·05	0·31	6·24	0·78
	2. Nil	32·73	33·18	0·70	19·40	2·18	10·86	0·23	6·35	0·72
	3. Mg & K	33·57	32·74	0·80	21·75	2·27	10·99	0·27	7·30	0·75
	4. K	32·41	33·12	0·62	21·63	2·47	10·41	0·20	7·01	0·78

The chemical data in Table I show an increase of both potassium and magnesium in the leaves where these ingredients were applied. It is evident that the plants accumulated both calcium and potassium in the leaves as the season progressed, whilst the reverse was true of magnesium. Phosphorus also showed a seasonal decrease which is a normal feature for this element.

It may be noted that on 20/4/44, when no magnesium deficiency symptoms were apparent, the value for MgO in the leaves was approximately 0·40% D.M.

Centre II.

The treatments at this centre were the same as for Centre I.

The magnesium sulphate and base dressings were applied on 1/2/44 and the house planted some days later.

Observational Data.

Early growth at this centre was of normal appearance and there was a good set of fruit. No magnesium deficiency symptoms showed until the middle of May.

On 19/5/44 the visual symptoms on the two magnesium treated plots were slight and very slight respectively, whilst on the untreated plots severe and medium were recorded. The application of potash on plots 3 and 4 had no effect on the severity of the symptoms.

Severity of Magnesium Deficiency Symptoms.

Date.	Plot 1.	Plot 2.	Plot 3.	Plot 4.
20/4/44	Nil	Nil	Nil	Nil
19/5/44	Slight	Severe	Very Slight	Medium
4/7/44	Slight	Severe	Slight	Severe

Chemical Data.

The chemical data on the leaf samples taken on the above dates are presented in Table II.

TABLE II.

Date.	Plots & Treatment.	Ash as % D.M.	As % Ash.				As % Dry Matter.			
			CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
20/4/44	1. Mg	15·29	25·55	3·86	28·43	8·15	4·91	0·59	4·35	1·24
	2. Nil	13·99	21·79	3·70	29·92	9·80	4·70	0·52	4·19	1·37
	3. Mg & K	16·10	25·73	3·62	27·91	8·56	4·68	0·58	4·49	1·37
	4. K	15·87	27·04	3·40	26·57	8·50	4·89	0·54	4·22	1·34
19/5/44	1. Mg	23·36	30·69	1·91	19·67	4·42	7·17	0·45	4·60	1·03
	2. Nil	23·28	30·78	1·15	19·75	4·18	7·16	0·27	4·53	0·97
	3. Mg & K	24·83	30·43	1·52	20·65	3·93	7·56	0·37	5·13	0·98
	4. K	25·07	30·56	1·23	21·40	4·55	7·66	0·31	5·37	1·14
4/7/44	1. Mg	29·94	33·73	1·57	19·34	3·02	10·11	0·47	5·79	0·90
	2. Nil	27·12	36·49	0·80	20·80	3·47	9·89	0·23	5·64	0·94
	3. Mg & K	30·85	33·22	1·29	22·33	2·62	10·25	0·47	6·89	0·81
	4. K	27·26	36·17	0·82	23·62	3·06	9·86	0·23	6.44	0·85

The chemical data agree well with the visual observations. The magnesium status of the leaves at the first sampling is high in both treated and untreated plots, whilst the values for MgO in the second and third sampling not only give lower figures than the first sampling, but reflect clearly the poorer status of untreated plots. At this centre magnesium deficiency symptoms were apparent with a value for MgO of 0·45% D.M.

The accumulation of calcium and potassium in the leaves of the older plants and the effect of potash treatment in raising the potassium status is again clearly seen in the chemical data.

Centre III.

At this centre two series of experiments were carried out. The first was carried out on an early planting, the experimental treatments being identical with those at Centres I and II. The second experiment was made on a late planting in a different house where magnesium deficiency had previously been very severe.

Experiment I.

The plots used in this experiment were the same as those utilised in the 1943 experiment.

The whose house received 2–3 tons per acre of mushroom mould with the normal base dressing, without potash on plots 1 and 2 and with potash included on plots 3 and 4.

Magnesium sulphate at 6 cwt. per acre was applied on 21/2/44 and the house planted the following week.

Observational Data.

Severity of Magnesium Deficiency Symptoms.

Date.	Plot 1.	Plot 2.	Plot 3.	Plot 4.
19/5/44	Nil	Nil	Nil	Nil
26/6/44	Nil	Very Slight	Trace	Very Slight
14/7/44	Trace	Medium	Slight	Medium

The visual symptoms did not develop to any serious extent in this house. The results were similar to those obtained in 1943, when it was suggested that steam sterilisation had given a partial control. It should also be noted that the symptoms were definitely less severe than at Centres I and II.

Chemical Data.

TABLE III.

			As % Ash.				As % Dry Matter.			
Date.	Plots & Treatment.	Ash as % D.M.	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
19/5/44	1. Mg	23·55	31·38	2·69	19·32	4·12	7·26	0·62	4·55	0·95
	2. Nil	21·28	33·82	2·29	20·58	4·50	7·20	0·49	4·38	0·96
	3. Mg & K	23·25	30·69	2·84	21·94	4·17	7·14	0·66	5·10	0·97
	4. K	20·86	30·80	2·42	22·96	5·20	6·42	0·51	4·79	1·09
14/7/44	1. Mg	31·72	33·17	1·58	18·63	2·32	10·52	0·50	5·91	0·74
	2. Nil	30·65	34·35	1·12	18·37	2·03	10·51	0·31	5·63	0·62
	3. Mg & K	32·14	32·80	1·37	21·59	2·24	10·54	0·43	6·94	0·72
	4. K	30·59	34·87	1·05	21·34	2·12	10·67	0·32	6·53	0·65

The relationship between observational and chemical data is again close. Deficiency symptoms were just visible when MgO value was 0·50% D.M.

The potash treatment, although reflected in the chemical data, provided no significant effects on the severity of magnesium deficiency.

Experiment 2.

The second experiment at this centre was designed to compare the effects of magnesium sulphate applied as a soil dressing at different rates, as a solution applied to the soil and as a foliage spray.

For the purpose of the experiment the house was divided into 12 plots, in two blocks (A and B), and the following treatments given in duplicate and distributed at random.

1. Magnesium Sulphate at 5 cwt. per acre applied as base dressing.
2. ,, ,, ,, 10 ,, ,, ,, do.
3. ,, ,, ,, 15 ,, ,, ,, do.
4. ,, ,, ,, 20 ,, ,, ,, do.
5. ,, ,, as 2½% foliage spray at intervals during growth.
6. ,, ,, as 2½% solution applied to soil around the roots at times and amounts as in 5.

The controls for this experiment were taken from an adjacent house where conditions were comparable in all respects to the experimental house.

A base fertiliser dressing was given throughout the house and the magnesium sulphate in treatments 1 to 4 was applied to the soil on 4/8/44. Planting was carried out on 7/8/44. Spray and watering treatments were commenced on 18/8/44 and were subsequently repeated at intervals of three weeks.

In all, five 2½% sprays were applied at the rate of 600 gallons per acre to plot 5*a*, making a total of approximately 6 cwt. of magnesium sulphate for the season. Plot 5*b* received four 2½% spray applications, making a total of 5 cwt. per acre. The spray was applied with a stirrup pump, using a spray nozzle. The wetting agent used was sulphonated lorol at the rate of 8 ozs. per 100 gallons of spray.

Observational Data.

All plants showing visual symptoms, irrespective of severity, were recorded for each plot at intervals. The number of plants affected are expressed as a percentage of the total number (150) of plants per plot.

Records for three dates are given in Table IV.

TABLE IV.

PERCENTAGE OF MAGNESIUM DEFICIENT PLANTS IN BLOCKS A AND B AT VARIOUS INTERVALS.

Treatment	25/10/44			13/11/44			5/12/44		
	Block A	Block B	Average	Block A	Block B	Average	Block A	Block B	Average
5 cwt.	8·0	9·3	8·6	24·0	22·7	23·3	28·0	23·3	25·6
10 cwt.	5·3	4·0	4·6	6·0	8·7	7·3	10·7	15·3	13·0
15 cwt.	5·3	6·0	5·6	6·6	12·0	9·3	13·3	19·3	16·3
20 cwt.	2·0	4·7	3·3	7·3	6·7	7·0	12·7	17·3	15·0
Spray (2½%) ..	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Solution (2½% to soil)	12·7	10·7	11·7	19·3	18·7	19·0	24·0	25·3	24·6
Control	—	—	—	37·3	39·3	38·3	43·3	42·7	43·0

From Table IV it is clear that all treatments reduced the incidence of visual symptoms. A poor control was obtained with the 5 cwt. per acre dressing and also by the watering method where the total applications amounted to 6 cwt. per acre. The application of 10, 15 and 20 cwt. per acre gave a good commercial control of visual symptoms and no advantage followed from increasing the amount above 10 cwt.

Complete control was obtained by the spraying method where the amount used was 5 cwt. per acre (4 sprayings), thus showing the superiority of the spraying method over both methods of soil application used.

No spray damage occurred until after the fourth applications when some damage was recorded. However, the flower trusses and yields were not affected.

Chemical Data.

Leaf samples were taken for analysis on each of the three recording dates.

TABLE V.

MEAN % OF DUPLICATE TREATMENTS FROM BLOCKS A AND B.

			As % Ash.				As % Dry Matter.			
Date.	Plots & Treatment.	Ash as % D.M.	CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
2/10/44	1. 5 cwt.	22·87	30·47	2·47	17·18	3·79	6·92	0·56	3·85	0·87
	2. 10 cwt.	23·38	34·78	2·99	16·03	3·63	8·20	0·70	3·73	0·85
	3. 15 cwt.	24·02	34·88	2·85	16·74	3·93	8·37	0·71	3·71	0·94
	4. 20 cwt.	25·48	34·18	2·61 *	18·59	4·02	8·63	0·68 *	4·02	1·02
	5. Spray	24·01	29·54	3·07	17·14	4·28	7·12	0·86	4·12	0·88
	6. Liquid applic.	23·71	33·79	2·47	17·80	4·27	8·10	0·58	4·21	0·88
	7. Control	—	—	—	—	—	—	—	—	—
14/11/44	1. 5 cwt.	25·62	42·37	1·59	18·78	3·85	10·52	0·39	4·67	0·95
	2. 10 cwt.	29·07	39·92	1·81	14·04	2·78	10·00	0·51	4·12	0·80
	3. 15 cwt.	30·07	37·86	1·74	16·14	2·73	11·38	0·52	4·83	0·81
	4. 20 cwt.	29·38	37·20	1·48 *	15·94	2·83	11·62	0·43 *	4·68	0·84
	5. Spray	29·77	31·60	5·88	12·87	3·17	9·42	1·75	3·78	0·95
	6. Liquid applic.	30·78	35·75	1·28	16·12	3·17	11·00	0·39	4·95	0·97
	7. Control	27·13	35·01	0·37	18·38	2·76	9·50	0·10	4·92	0·75
5/12/44	1. 5 cwt.	30·12	37·15	1·25	16·79	2·64	11·32	0·38	5·10	0·79
	2. 10 cwt.	27·74	35·65	1·47	18·91	2·55	9·76	0·41	5·26	0·75
	3. 15 cwt.	30·23	38·92	2·06	15·78	2·73	11·78	0·62	4·63	0·80
	4. 20 cwt.	27·00	40·90	1·57 *	16·74	2·95	10·85	0·42 *	4·65	0·79
	5. Spray	30·84	34·99	6·20	12·32	2·44	10·78	1·90	3·76	0·75
	6. Liquid applic.	29·48	34·48	0·87	18·98	3·02	10·23	0·26	5·57	0·89
	7. Control	26·68	35·38	0·49	21·79	2·96	9·44	0·13	5·81	0·79

* MgO figures may be too high due to the accumulation of magnesium sulphate on the leaf surface from sprays.

From Table V it is evident that the magnesium status of the control plot is very low and agrees with the observational data. All plots, irrespective of treatment in the first sampling, have an adequate magnesium status. The MgO content, however, falls as the season progresses except for treatment 5 (spray), which shows a slight increase.

Although treatment 6 has received an equivalent amount of magnesium sulphate (as liquid fertiliser) to treatment 5 (foliage spray), the falling off of the magnesium content of the foliage is very marked, indicating that this form of soil treatment is unsatisfactory.

It appears that the addition of 10 cwt. per acre of magnesium sulphate is the most effective and economic of the soil treatment.

Whilst a high magnesium status is indicated by the chemical data on the spray plot plants, it should be noted that the figures may be too high due to the accumulation of magnesium sulphate on the surface of the leaves.

Centre IV.

Magnesium deficiency was very severe at this centre in 1942 and in 1943, and three experiments were laid down to compare the effect of spraying the foliage with a solution of magnesium sulphate with a soil application as a base dressing.

Experiment 1.

The house was divided into four plots ; plots 1 and 3 received magnesium sulphate at the rate of 6 cwt. per acre on 15/2/44, plot 2 was left untreated as a control, and plot 4 was scheduled to be sprayed at intervals with $2\frac{1}{2}\%$ magnesium sulphate. The house was planted on 27/2/44.

Owing to the pressure of work the spray was only put on once, during the period 20/4/44 to 19/5/44, at the rate of 150 gall. per acre. Some very slight symptoms of magnesium deficiency were present before the spraying was carried out.

Observational Data.

Severity of Magnesium Deficiency.

Date.	Plot 1	Plot 2	Plot 3	Plot 4
20/4/44	Nil	Nil	Nil	Nil
19/5/44	Nil	Medium	Slight	Very Slight
4/7/44	Slight	Medium Severe	Slight	Slight Medium

From the observational data it is clearly seen that both soil application and foliage spraying with magnesium sulphate had a marked effect on the incidence of magnesium deficiency at this centre. One spray applied to plot 4 considerably arrested the spread of the symptoms to the upper parts of the plant.

Chemical Data.

Samples for chemical analysis were taken on each of the above dates and the results are recorded in Table VI.

The chemical data do not show any difference in MgO content on the first sampling date, but in subsequent samplings a difference is clearly seen. It is interesting to note that one spraying with magnesium sulphate increased the MgO content to a value of 0.46% MgO in the second sampling. About a month later, when the third sampling was completed, the value had dropped to 0.39%, with the simultaneous development of very definite symptoms.

TABLE VI.

Date.	Plots & Treatment.	Ash as % D.M.	As % Ash.				As % Dry Matter.			
			CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
20/4/44	1. Mg	16·12	31·32	3·09	23·58	6·74	5·05	0·50	3·80	1·08
	2. Nil	17·00	28·27	2·66	23·19	6·45	4·80	0·45	3·94	1·09
	3. Mg	16·46	29·66	2·65	23·37	5·98	4·88	0·44	3·81	0·98
	4. Spray	15·05	28·77	2·61	25·64	6·37	4·33	0·39	3·86	0·96
19/5/44	1. Mg	20·80	30·53	2·43	20·67	5·41	6·35	0·48	4·30	1·08
	2. Nil	18·65	32·92	1·51	22·41	5·30	6·15	0·28	4·18	0·99
	3. Mg	20·14	34·95	1·64	22·34	4·78	7·04	0·33	4·50	0·96
	4. Spray	18·87	35·74	2·42	22·31	4·75	6·74	0·46	4·21	0·90
4/7/44	1. Mg	22·88	33·04	1·57	20·50	3·40	7·55	0·36	4·69	0·78
	2. Nil	21·88	33·68	1·12	20·24	3·59	7·57	0·25	4·43	0·79
	3. Mg	24·17	34·56	1·26	19·78	3·85	8·36	0·30	4·78	0·93
	4. Spray	24·70	36·36	1·58	19·84	3·69	8·98	0·39	4·90	0·91

Experiment 2.

This experiment was carried out in a house adjoining that used for experiment 1, and was again designed to determine the effect of spraying the plants with $2\frac{1}{2}\%$ magnesium sulphate. The house was divided into four plots, two being sprayed and the other two left as controls. (The rate and time of application and the strength of spray are the same as for experiment 1.) Only one spraying was applied and this resulted in an initial control, but symptoms appeared later on in the season.

Chemical Data.

The leaf samples were taken for analysis from both sprayed and unsprayed plots on 19/5/44. The results are presented in Table VII.

TABLE VII.

Date.	Treatment.	Ash as % D.M.	As % Ash.				As % Dry Matter.			
			CaO	MgO	K_2O	P_2O_5	CaO	MgO	K_2O	P_2O_5
19/5/44	Control	18·0	30·7	1·09	22·7	4·6	5·5	0·19	4·4	0·83
	Sprayed	21·0	33·9	1·84	20·2	4·4	7·1	0·39	4·2	0·94

One spray application increased the MgO content of the leaves from 0·19% in the control to 0·39% in the sprayed plot with corresponding decrease in the severity of deficiency symptoms.

Experiment 3.

Experiment 3 was also planned to ascertain the effect of spraying with 2½% magnesium sulphate as a means of controlling the deficiency. The variety Vetomold was used and was planted on 20/6/44. The house was divided into four plots, two of which were sprayed. The spray was applied at the rate of 150 gall. per acre and with three spray applications 1 cwt. per acre of magnesium sulphate was applied.

Observational Data.

Severity of Magnesium Deficiency Symptoms.

Date.	Control Plots.	Sprayed Plots.
20/7/44	Nil	Nil
11/8/44	Slight	Nil
6/9/44	Severe	Nil
20/9/44	Severe	Nil

It is significant that with very light spraying no magnesium deficiency symptoms appeared on the treated plots.

No chemical data were obtained on these plots.

Centre V.

The trial at this centre was also designed to test the effect of spraying with 2½% magnesium sulphate solution. The experiment comprised four sprayed plots and four controls in two houses, using the variety Stonor's Moneymaker planted on 10/3/44. Five spray applications were given at intervals of about 2 weeks between June 9th and August 11th, at the rate of 150 gallons per acre, using in all approximately 1½ cwt. per acre of calcined kieserite.

Observational Data.

Severity of Magnesium Deficiency Symptoms.

Dates of Spraying and Recording.	Control Plots.	Sprayed Plots.
9/6/44 ..	Lower leaves yellowing	Lower leaves yellowing
19/6/44 ..	Yellowing progressing	No more yellowing
6/7/44 ..	Yellowing progressing further	do.
27/7/44 ..	Few green leaves left	do.
11/8/44 ..	Very few green leaves left	do.

It will be seen from the above data that definite symptoms of magnesium deficiency had appeared before the first spray application and that spraying did not revive the affected leaves but completely arrested the spread of the chlorosis to the younger foliage. The plants in the control plots ceased growing much earlier than the sprayed plants and the top growth was very weak and spindly, resulting in a very poor set and much loss of crop.

The experiment showed that the spraying treatment was adequate to control the deficiency.

Discussion.

The two main objects in the 1944 experiments were to examine the effects of various soil applications of calcined kieserite as base dressings and to compare the effects of soil dressings and foliage spray treatments.

The trials at Centres I, II and III, Experiment 1, show that considerable control of magnesium deficiency can be obtained by the application of magnesium sulphate as calcined kieserite (30% MgO) at 6 cwt. per acre. Contrary to 1943 results, the addition of potash to the base dressing did not accentuate the severity of magnesium deficiency symptoms.

Experiment 2 at Centre III, designed to compare the effect of spraying the plants with fairly heavy applications of magnesium sulphate, with soil dressings of this material at various rates, showed that considerable control could be obtained from all treatments. The data indicate that a soil dressing of 10 cwt. is necessary to obtain a satisfactory degree of control. It is noteworthy that applications in excess of 10 cwt. per acre did not further reduce the severity of the deficiency. Spraying at this centre, using 2½% solution in four applications, each of 600 gall. per acre, equivalent to 5 cwt. magnesium sulphate per acre, gave a complete control, but foliage damage occurred after the fourth application.

The spraying results recorded at Centre IV, experiment 3, and Centre V, experiment 3, with applications approximately ⅛th of the quantities used in Centre III (*i.e.* 1 cwt. magnesium sulphate), show that complete control was obtained without any spray damage to the foliage. Evidence from Centre IV, experiments 1 and 2, where one 2½% spray was applied, indicate that this is only sufficient to arrest temporarily the development of magnesium deficiency. The improvement effected was followed by the reappearance of visual symptoms and a decrease in the MgO content of the leaves below a value of 0·40%. Three sprays at 150 gallons per acre at this centre were sufficient to control completely any foliar symptoms.

The experiments have shown clearly the superiority of spray treatments over soil applications, both as regards effectiveness and economy in magnesium sulphate.

Further work is however necessary to determine the best strength of spray, the most suitable rate of application to be effective but to avoid foliage damage, and the minimum number of applications required to control the deficiency throughout the entire growing period.

It should be noted that the calcined kieserite (30% MgO) used in these experiments is approximately twice as concentrated as agricultural Epsom Salts (16% MgO), and if the latter material is used the rates should be approximately twice those given herein.

Since the centres have of necessity been limited in number, growers wishing to test the effects of spray treatments should proceed with caution until it is ascertained that sprays will not produce damage under their particular conditions. A spray of 1% Epsom Salts will perhaps form a suitable starting point and it is important that a spreader be used, otherwise damage will result.

The chemical data obtained suggest that a midseason value of 0·50% MgO in leaves from the mid-stem portion of the plant, may be regarded as a threshold value between sufficiency and deficiency of the element. The value may, of course, vary with different varieties and environmental conditions, and should only be regarded as an approximate index.

Summary and Conclusions.

Experiments on the control of magnesium deficiency in glasshouse tomatoes were continued at the three centres used in 1943, and at two additional centres where the trouble had been serious in previous seasons.

The objects of the experiments were (1) to ascertain the degree of control of the deficiency obtainable by a base dressing to the soil of magnesium sulphate (30% MgO) at 6 cwt. per acre; (2) to compare the effects of base dressings at rates varying from 6 cwt. to 20 cwt. magnesium sulphate per acre; (3) to compare the effectiveness of magnesium sulphate used as a foliage spray, as a fertiliser in a base dressing and in solution form applied to the soil during the growth period.

Soil dressings in the base fertiliser at 6 cwt. per acre only gave partial control and a rate of 10 cwt. per acre was necessary to obtain satisfactory commercial control. Dressings in excess of 10 cwt. per acre were no more effective.

Liquid dressings to the soil during the growing period were relatively ineffective at a total rate of 5 cwt. per acre.

Spraying treatments were very effective, much more so than soil applications. Complete control in severe instances was obtained by 3 or 4 sprayings during the growing season, using total amounts of magnesium sulphate (30% MgO) as low as 1½ and 5 cwt. per acre respectively.

Further experiments are required to obtain more precise data relative to best strength of spray, volume of spray solution and minimum number of applications required, to obtain effective control without damaging the foliage.

Chemical data on leaves from the mid-stem region suggest a value of 0·50% MgO in dry matter as a threshold value between sufficiency and deficiency of the element.

Acknowledgments.

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MANURIAL EXPERIMENTS ON VEGETABLE CROPS.

VII. EFFECTS OF FARMYARD MANURE AND OF VARIOUS FERTILISER TREATMENTS ON GARDEN BEET.

By P. T. H. PICKFORD.

The results presented in this paper are for garden beet, the sixth crop of the series in which the previous crops were savoys, carrots (1), onions (2), spring cabbage and cauliflower (3). The layout of the plots and the scheme of manurial treatments has been described in a previous paper (1). For garden beet the farmyard manure dressing was maintained at 10 tons per acre, the rate applied to the previous three crops. The nitrogen dressing for the other plots was at 3 cwt. per acre of nitro-chalk.

Four varieties of garden beet, namely Detroit Red Globe, Obelisk, Covent Garden Red and Cheltenham Green Top were sown on 25th April. Germination was poor owing to dry weather conditions, and the variety Detroit had to be completely resown on 19th May, while Cheltenham Green Top was partially resown on the same date.

Results.

Observations on the growth of the plants were made on July 31st. Table I indicates the relative growth for the different treatments. The maximum number of points possible is twelve.

TABLE I.

Complete Fertiliser (N.P.K. with Sulphate of Potash).	Farmyard Manure.	Potash Omitted.	Phosphate Omitted.	Nitrogen Only.	Nitrogen Omitted.	Nitrogen, Phosphate, & Muriate of Potash.	Nitrogen, Phosphate and Salt.
10	9	8½	7½	6½	4½	11	11

Growth was slow through the summer months owing to the continual dry weather and except for Detroit the crop was not harvested until October.

Detroit matured first and most of the crop of this variety was lifted on August 14th. The small roots were left until the rest of the beet was lifted in October. The total yields per plot were recorded. The yields, excluding those from the muriate of potash and salt plots which are separate from the main experiment, were analysed statistically and the results are given in Table II.

TABLE II.

Crop Weights of Variety Detroit (Tons per Acre).

Complete Fertiliser, with K_2SO_4.	Farmyard Manure.	Phosphate Omitted.	Potash Omitted.	Nitrogen Omitted.	Nitrogen Only.	Nitrogen, Phosphate, Muriate of Potash.	Nitrogen, Phosphate, Salt.
10·75	10·18	7·77	6·79	5·72	3·92	13·26	15·53

S.E. 0·72 tons.
Difference required for significance at 5% pt. 2·26 tons.
" " " " " 1% pt. 3·20 "

There was no significant difference between the complete fertiliser and the farmyard manure treatments, but these two treatments were significantly higher than the other four treatments at the 5% point, while at the 1% point they were significantly higher than all but the phosphate omitted treatment. At the same time the phosphate omitted treatment gave a significantly higher yield than the nitrogen only treatment at the 1% point, while potash omitted treatment gave a bigger yield than the nitrogen only treatment at the 5% point.

The yields from the muriate of potash and the salt plots were higher than for any other treatment, but these were not included in the statistical analysis, as they are not strictly comparable with the main series. No harmful effect was apparent from these chloride-containing fertilisers, which appear to be very suitable for this crop.

The results indicate the importance of a complete manurial treatment for this variety of garden beet. The omission of phosphate appeared to be rather less serious than the omission of potash or nitrogen, and a very poor yield resulted where both phosphate and potash were omitted and nitrogen only was applied.

The other three varieties could not be lifted until mid-October and the harvesting had to be spread over a long period extending into November owing to the exceptionally bad weather conditions. The crop weights were recorded, but no significant differences were found between the yields from any of the treatments. The yields from these late maturing varieties may have been affected more by the exceptional weather conditions than by the various manurial treatments.

Very dry conditions in the early stages of their growth was followed later by a series of excessively wet periods, and on several occasions some of the plots were actually waterlogged for short periods.

Summary.

1. A description is given of manurial experiments on garden beet, this crop continuing the rotation reported in Parts I, III and V of this series.

2. Four varieties were sown, but the early maturing variety Detroit was the only variety which showed significant differences in yield following the various treatments.

3. The results from the variety Detroit indicate the importance of a complete manurial treatment for beet. The omission of either phosphate, potash or nitrogen decreased the yield considerably.

Acknowledgments.

This series of experiments was originated and carried out under the general direction of Professor Wallace, to whom the writer's thanks are due. The writer wishes also to acknowledge the assistance given by Miss J. G. Adams and Miss E. J. M. Prescott in recording the crop weights.

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MANURIAL EXPERIMENTS ON VEGETABLE CROPS. VIII. EFFECTS OF FARMYARD MANURE AND OTHER MANURIAL TREATMENTS ON CAULIFLOWER.

By P. T. H. PICKFORD.

The cauliflower crop discussed in this paper was the sixth crop in the series in which the previous crops were savoy, early potatoes (1), spring cabbage and carrots (2), and onions (3). The manurial treatments and the arrangement of the experiment are described in a previous paper (1). The fertilisers used and the rates of application were the same as for the previous crop with the following adjustments and alterations.

The standard dressing for nitrogen was nitro-chalk at 8 cwts. per acre; half was applied at planting and half as a top-dressing. The high rate farmyard manure dressing, which was previously at 10 tons per acre, was increased to 20 tons per acre. The low rate farmyard manure treatment, which is supplemented with half the standard rate of inorganic nitrogen, was increased from 5 to 10 tons per acre. Similarly, the vegetable compost treatment was increased from 5 to 10 tons per acre again with half the standard rate of inorganic nitrogen. The hoof and the sludge-straw compost plots were applied at rates to supply twice the nitrogen in the nitro-chalk dressing.

The cauliflowers, variety November (Clucas), were planted on the plots on June 13th at a distance of 2 ft. apart each way. On July 19th top dressings of nitrogen were given according to the scheme. the only plots not receiving nitrogen at that time being the high rate farmyard manure and the sludge-straw compost plots.

Results.

Observations on Growth. Growth on all plots was very good. On August 14th the plots were marked for vigour. The points awarded for the various treatments are given in Table I, the total possible points for each treatment being 12.

TABLE I.

Farmyard Manure (20 tons)	Sludge-Straw Compost	Farmyard Manure and Inorganic Nitrogen	Complete Fertiliser with Hoof	Complete Inorganic with Potash Salts	Complete Inorganic with Sulphate of Potash	Complete Inorganic and Magnesium Sulphate	Compost and Inorganic Nitrogen
10½	10½	10¼	9½	9½	9¼	9¼	8½

Crop Weights. The cauliflowers were cut between October 18th and December 7th, and total yields per plot were recorded. The yields were analysed statistically and are given in Table II.

TABLE II.

Yields of Cauliflowers (Tons per Acre).

Complete Fertiliser with Hoof	Complete Inorganic with Potash Salts	Sludge-Straw Compost	Farmyard Manure (20 tons)	Farmyard Manure (10 tons) and Inorganic Nitrogen	Complete Inorganic and Magnesium Sulphate	Complete Inorganic with Sulphate of Potash	Compost and Inorganic Nitrogen
11·29	10·99	10·59	10·09	10·07	9·96	9·88	9·34

S.E. 0·45 tons.

Difference required for significance at 5% pt. 1·36 tons.

,, ,, ,, ,, ,, 1% pt. 1·88 tons.

The plots which received the basal dressing of hoof gave the highest yield which was significantly greater than the vegetable compost treatment at the 1% point, while at the 5% point the hoof gave a significantly greater yield than the complete inorganic fertiliser with sulphate of potash. The complete inorganic fertiliser with potash salts was second in the order of yield, but here the yield was only significantly greater than that from the vegetable compost

treatment at the 5% point. The rest of the treatments show small differences in yield, none of which were significant. These results indicate that the inclusion of hoof as the nitrogenous base in a complete fertiliser has a beneficial effect on the yield of cauliflower. The use of potash salts as the source of potash in a complete fertiliser has no adverse effect. With regard to the vegetable compost treatment, which resulted in the lowest yields, it is apparent in the light of these results that this treatment at the rate applied was less effective as a source of nutrient for cauliflowers than the complete fertiliser with hoof or the complete inorganics with potash salts.

Summary.

1. Results are given on the effect of various fertiliser treatments on the yields of cauliflower.

2. Complete fertiliser using hoof as the basal nitrogen gave a significantly higher yield than a complete fertiliser with sulphate of potash.

3. The vegetable compost treatment resulted in a significantly lower yield than the complete fertiliser with hoof and the complete fertiliser with potash salts.

Acknowledgments.

The author's thanks are due to the Director, Professor Wallace, who originated the experiments, for his advice given during this season's work.

The author is indebted to Miss J. G. Adams and Miss E. J. M. Prescott for their help in recording crop weights.

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PLACEMENT EXPERIMENTS IN THE USE OF FERTILISERS.

PROGRESS REPORT, 1944.

By E. J. HEWITT.

Introduction.

Experiments reported recently (1, 2, 3, 4) have indicated certain advantages in applying fertilisers in close proximity to individual plants or seed drills as opposed to broadcast dressings ; such methods are referred to as placement methods and include the use of liquid " starter " solutions applied at the time of drilling or transplanting, liquid top dressings, and solid " band " placements in close relation to seed drills.

The main advantages claimed are :—

1. Enhanced root action in early growth with consequent improvement in vigour and earlier maturity.

2. Considerable economy in use of fertilisers on a basis of comparable or even improved yields.

These advantages, it is claimed, more than outweigh the additional time and labour required.

In order to test claims made for the liquid treatments under conditions and cultural practices obtaining in this country a series of preliminary trials was laid down on a statistical basis to compare the results of using liquid starters and top dressings with broadcast dressings and solid top dressings. Both seeded and transplanted crops were included.

Materials and Methods.

The crops grown and the treatments applied are summarised in Table I, with the rates of application of fertiliser. The fertiliser chosen was " National Growmore Fertiliser," having an analysis of 7% N, 7% P_2O_5 and 7% K_2O. The fertiliser was mixed with water 2–4 hours before use and applied partly in solution and partly in suspension ; frequent stirring was necessary in order to ensure even distribution.

Liquid starter solutions were applied by hand from a measure or watering can. Seeds were drilled from a " Planet " hand drill. All plots were cultivated by regular hoeing. Tomatoes were copper-sprayed twice during the season and the cauliflowers ringed with calomel at planting.

Results.

The mean numerical yields and significant differences are summarised in Table II. Cauliflowers responded well to a liquid treatment at planting following a broadcast dressing ; the latter with the " starter " gave early and total yields significantly higher than those obtained from the rest except broadcast-plus-water, and starter-plus-solid top dressing for total yield. The differential effects were more pronounced at the first cutting than in the total crop. Tomatoes showed an outstanding response to the treatment in which starter solution was given to the seed boxes five days before transplanting. Both the yield of ripe fruit and the total crop were increased significantly over those from the untreated plots and the effect on earliness was also highly significant over all other treatments. The starter solution given at the time of transplanting resulted in yields significantly greater than the untreated but not significantly different from the water-at-planting treatment.

The effect of liquid treatments applied when drilling seeded crops was very different from the effects on transplanted ones. Emergence was delayed in all cases ; due probably, in part, to caking of the soil above the seed, since with the globe beet, water at drilling significantly reduced the yield below that of the untreated plots, while the starter solutions did not have a significant effect. The broadcast dressing plots produced significantly higher yields than the starter and untreated plots. Similar but smaller differences were observed for the beet variety Intermediate drilled alternately with the globe beet. The total yield of peas from liquid starter-plus-liquid top dressing plots was significantly higher than from broadcast and untreated plots and the yield from liquid starter plots was significantly higher than from untreated plots. The lettuce plots were so variable that the effects of treatments could not be observed.

Summary.

1. Experimental plots, conforming to statistical requirements, were laid down to test the relative effects of liquid starter and top dressing solutions as compared with solid broadcast applications of fertiliser.

2. Transplanted crops, including tomatoes and cauliflowers, benefitted significantly from liquid treatments both in earliness and total yields.

TABLE I.—SUMMARY OF CROPS GROWN AND TREATMENTS GIVEN.

Crop and Variety.	Date and Conditions.	Treatments.	Concn. of Fertiliser and rate of application.	Wt. and Vol. per acre.
A. *Seeded Crops.*	Sown 25/4/44	A. Untreated	—	—
Garden Beet	Rows 14″ apart (dry)	B. Water after drilling	2 pints per 10′ of drill (all seeded crops)	200 lb. in 1000 gall. per acre
(i) Covent Garden Red (Intermediate)		C. Starter soln. after drilling	10 lb./50 gall.	
(ii) Detroit Select Red (Globe)		D. Solid broadcast	2 lb./10 sq. yds.	900 lb. p.a.
Lettuce	Sown 27/4/44	A. Untreated	—	—
All Year Round	Rows 14″ apart (dry)	B. Liquid starter soln.	10 lb./50 gall. 2 pints/10′	200 lb.—1000 g.p.a.
	Top dressed 4/6/44	+ Liquid top dressing	30 lb./50 gall. ½ pint per plant	600 lb.—1200 g.p.a.
		C. Liquid starter only	10 lb./50 gall. 2 pints—10′ drill	200 lb.—1000 g.p.a.
		D. Solid broadcast	2 lb./10 sq. yds.	900 lb.—p.a.
Pea	Sown 27/4/44	A. Untreated	—	—
Onward	Rows 2′ 6″ apart (dry)	B. Liquid starter	10 lb./50 gall. 2 pints/10′	100 lb.—500 g.p.a.
	Top dressed 14/6/44	+ Liquid top dressing	20 lb./50 gall. 5 pints/10′	500 lb.—1250 g.p.a.
		C. Liquid starter only	10 lb./50 gall. 2 pints—10′	100 lb.—500 g.p.a.
		D Solid broadcast	2 lb./10 sq. yds.	900 lb. p.a.
B. *Transplanted Crops.*	Transplanted 7/6/44	A. Untreated	—	—
Tomato	2′ 4″ x 2′ 6″ (dull & dry)	B. Starter soln. given to seed box 5 days prior to transplanting	10 lb./50 gall.	6 lb.— 30 g.p.a.
Market King		C. Water ditto	1 gall/25 plants	— 30 g.p.a.
		D. Starter soln. at time of transplanting	10 lb.—50 gall.	120 lb.—600 g.p.a.
		E. Water ditto	at ½ pint per plant	—600 g.p.a.
Cauliflower	Transplanted 14/6/44	A. Solid broadcast+water at transplanting	2 lb.— 10 sq. yds. water ¼ pint per plant	900 lb. p.a.
	2′ x 2′ (very dry)	B. Solid broadcast+liquid starter at planting	20 lb.—50 gall. at ¼ pint per plant	130 lb.—325 g.p.a.
		C. Solid broadcast only	2 lb.—10 sq. yds.	—
	Top dressed 14/8/44	D. Liquid starter	20 lb.—50 gall. at ¼ pint per plant	130 lb.—325 g.p.a.
		+ Liquid top dressings	at ½ pint per plant	260 lb.—650 g.p.a.
		E. Liquid starter + Solid top dressing	at ¼ pint per plant at 2 lb.—10 sq. yds.	900 lb. p.a.
		F. Solid top dressings only (to each plant)	at 2 lb.—10 sq. yds.	

TABLE II.

SUMMARY OF RESULTS. MEAN YIELDS.

A. *Seeded Crops.*

BEET.	Plots 1/100 acre	Covent Garden Red (Intermediate) Harvested 30/10/44	Detroit Select Red (Globe) Harvested 10/8/44 and 25/10/44
	Treatments	lbs. per plot	lbs per plot
	A. Untreated	101·8	69·1
	B. Water at drilling	85·6	46·1
	C. Starter at drilling	126·4	67·8
	D. Broadcast	148·1	92·8
t at 5% pt. = 2·45	S.E.	8·89	4·56
	Significant Diff. 5% pt.	30·80	15·80

PEA.	Plots 1/210 acre	First Picking (27/7/44)	Total Crop (8/8/44)
	A. Untreated	14·3	32·4
	B. Liquid starter+Liquid top dressing	14·8	38·1
	C. Liquid starter only	15·6	36·4
	D. Broadcast	12·9	33·9
t at 5% pt. = 2.45	S.E.	1·00	1·37
	Significant Diff. 5% pt. (between treatments)	3·41	3·81

B. *Transplanted Crops.*

TOMATO.	Plots 1/380 acre	1st two pickings (earliness) (12/9/44) lbs. per plot	Total Ripe (4/10/44) lbs. per plot	Total Ripe and Green lbs. per plot
	A. Untreated	3·1	21·1	63.7
	B. Starter to seed boxes	4·9	27·3	81.9
	C. Water to seed boxes	3·3	20·8	68 6
	D. Starter at planting	3·7	24·2	77·2
	E. Water at planting	3·7	23·6	74··6
t at 5% pt. = 2·18	S.E.	0·107	1·05	3·15
	Significant Diff. 5% pt. (between treatments)	0·34	3·23	9·70

CAULIFLOWER	Plots 1/180 acre	1st cutting (18/10/44) lbs. per plot	Total Crop harvested by 8/12/44 lbs. per plot	
	A. Broadcast + water at planting	58·5	113·0	
	B. Broadcast + starter at planting	72·5	121·6	
	C. Broadcast only	29·5	90·0	
	D. Starter + liquid top dressing	49·3	101·5	
	E. Starter + Solid top dressing	45·9	105·9	
	F. Solid top dressing only	25·3	87·4	
t at 5% pt. = 2·13	S.E.	7·33	6·64	
	Significant Diff. 5% pt. (between treatments)	22·07	20·00	

3. Tomatoes responded particularly well when the starter solution was given to the plants in boxes five days before planting out.

4. Seeded crops were delayed in emergence by liquid treatments; peas showed a significant increase of yield with liquid treatments, while for beets broadcast applications generally gave the highest yields.

Acknowledgments.

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THE TECHNIQUE OF CHEMICAL TISSUE TESTS. PROGRESS REPORT I.

By WILLIAM PLANT, J. O. JONES & D. J. D. NICHOLAS.

INTRODUCTION.

The method of chemical tissue tests originated in America and has been found of special value for corn and small grain crops on which the visual method presents difficulties (1, 2, 3).

Parallel tests for soils have also been developed and techniques suitable for use on both plants and soils have been described (4, 5, 6).

In this country the use of rapid chemical methods for controlling the composition of plant nutrient solutions has been studied by Fawcett and Stoughton and a comprehensive account of their technique and methods has been published (7).

The extensive use of the " Visual diagnosis " method for the identification of mineral deficiencies (8) in this country has shown the necessity for developing confirmatory field tests for crops such as cereals where symptoms may not be well marked, and for other crops where they may be masked by damage caused by insects, fungus diseases, and certain mineral elements present in excess.

Work on chemical tissue tests was commenced at Long Ashton during the winter of 1943 and as a first step in the development of methods, the co-operation of Professor R. H. Stoughton and Mr. G. S. Fawcett was sought with the object of attempting to adapt their chemical methods and equipment (7) to plant tissues. Considerable progress has been made and procedure and equipment have been designed for use both in the laboratory and the field.

In the present report a brief summary of the methods and equipment tentatively adopted are given; some results obtained by the use of the technique employed are given in another paper in this Report (p. 84).

EXPERIMENTAL METHODS.

Sampling.

Any material collected for the purpose of extraction requires to be as free from colouring matter as possible. It has been found most convenient to sample cereals between the internodes, and broad leaf crops at the petioles or mid-ribs; crops such as onions which do not fall into these categories should be sampled at the bases of the leaves. When collecting material for making comparisons between experimental plots random samples are taken; for the diagnosis of deficiencies in the field the procedure followed is to make comparisons between samples of good and bad plants.

Extraction.

The factors governing the extraction of the major and trace elements from plant material by means of buffered or unbuffered solutions are imperfectly understood. In practice, however, it is possible to obtain solutions containing nitrate, phosphate, potassium, calcium, magnesium and chloride by soaking cut up tissues in Morgan's reagent (pH 4·8) for 15 minutes. Trace elements such as iron and zinc when present in average or low amounts are not detected when this reagent is used, but can be extracted in quantity by hydrochloric acid. Morgan's reagent, however, will extract average and excessive amounts of manganese (Table I).

Standards.

Wherever possible an attempt has been made in this work to use colorimetric tests in order that discs fitting the Lovibond comparator might be used as permanent colour standards (7). Discs are available for nitrate, phosphate, potassium, magnesium and iron; the remaining elements have to be calibrated against stock solutions (Table I). For assessing results it has been found convenient to work with low, medium and high categories. These levels, which correspond to specific quantitative amounts of an element, have to be determined for each crop; further information relating to these standards appears in the following paper.

TABLE I.

Element	Extracting Solution	Calibration	Range of Disc or Standards
Nitrate	Morgan's reagent	Disc	5—100 p.p.m. N
Phosphate	,, ,,	,,	10— 80 ,, PO_4
Potassium	,, ,,	,,	10—100 ,, K
Calcium	,, ,,	Standards	10—100 ,, Ca
Magnesium	,, ,,	Disc	1— 10 ,, Mg
Chloride	,, ,,	Standards	—
Manganese (av. & excess)	,, ,,	,,	0·1— 10 ,, Mn
Iron (av. & excess) ..	Hydrochloric acid	Disc	0·2— 5 ,, Fe
Zinc (av. & excess) ..	,, ,,	Standards	—100 ,, Zn

Equipment.

In order to standardise the procedure for matching results of colour tests, the apparatus was adapted from that used by Fawcett and Stoughton (7).

The minimum equipment consists of an " All Purpose Lovibond Comparator," discs and cells (13·5 mm. and 2·5 mm.). An outfit embodying all the necessary features for carrying out the tests is being constructed by The Tintometer Ltd,

ESTIMATION OF MAJOR ELEMENTS.

Preparation of Samples.

Tests are generally carried out for nitrate, phosphate, potassium, calcium and magnesium.

Reagents.

1. Sodium acetate A.R. .. .. .. 100 gm.
   Glacial acetic acid A.R. .. .. 30 ml.

Make up to one litre with distilled water. This solution is known as Morgan's reagent (5).

Allowing 0·5 gm. of material for each test weigh out 3·0 gm. ; cut up the tissue with a razor blade into millimetre sections ; place the material in a beaker and add 30 ml. Morgan's reagent ; stand for 15 minutes. Pipette off separate lots of 5 ml. with a graduated delivery pipette into specimen tubes which are subsequently used for developing the tests.

The confirmation of a visual diagnosis of a major deficiency can be quickly obtained by the addition of the reagents to the Morgan's extract plus the tissue.

Nitrate Nitrogen.

Reagents.

1. Phenol disulphonic acid .. .. 25% w/v.
2. Ammonia solution A.R. .. .. 20% w/v NH_3.

Method.

Add 2 ml. of phenol disulphonic acid to the 5 ml. Morgan's extract, allow to stand for 5 minutes. Add 5 ml. distilled water and when cool make up to 20 ml. with ammonia. Again cool and dilute to 25 ml. with water. Fill a cell (13·5 mm.) with the yellow solution produced and match in the comparator with disc KZ.

Phosphate.

Reagents.

1. To 200 ml. of distilled water add 65 ml. of concentrated sulphuric acid A.R. and dilute to 500 ml.
2. Ammomium molybdate A.R. .. .. 8·8 gm.
   Distilled water .. .. 100 ml.
2*a*. Sulphuric acid conc. A.R. .. .. 5·3 ml.
   Distilled water .. .. 100 ml.

Mix (2) with (2*a*) and make up to 250 ml. with distilled water. Finally mix this 250 ml. with an equal volume of Reagent 1 and store in an amber bottle.

3. Hydroquinone (pure) .. .. .. 1·0 gm.
   Distilled water .. .. 100 ml.

Dissolve complete, and then add 0·5 ml. of Reagent 1. Must be remade after 3 weeks

4. Sodium carbonate anhydrous .. 100 gm.
   Sodium sulphite .. .. .. 24 gm.
   Distilled water .. .. 500 ml.

Method.

This test, which is a provisional one, should be carried out at 23°C. To

5 ml. of the Morgan's extract add 2 ml. of the molybdate solution and 1-ml. of the hydroquinone solution. Allow to stand 5 minutes for the green colour to develop ; add 2 ml. of the carbonate solution and mix thoroughly. Match immediately with disc KV.

Potassium.

Reagents.

1. Sodium cobaltinitrite solution made as follows :—
   Acetic acid A.R. .. .. .. 2·5 ml.
   Cobalt acetate A.R. .. .. .. 5·0 gm.
   Sodium nitrite .. .. .. 30·0 gm.

Dissolve in distilled water, and make up to 100 ml. The solution should be allowed to mature for 48 hours before use.

2. Iso-propyl alcohol.

Method.

To the 5 ml. of the Morgan's extract add 3 drops of cobaltinitrite reagent, mix and then add 2 ml. of iso-propyl alcohol. Invert the specimen tube twice ; stand for 2 minutes and decant the solution into the 2·5 mm. cell and match in the comparator. The time limit specified is important for the accurate determination of amounts.

Calcium.

Reagents.

1. Ammonium oxalate A.R. .. .. saturated solution.
2. Calcium chloride hydrated A.R. .. 0·547 g.m.
   Distilled water to .. .. .. 1000 ml.
   This stock solution equals 100 p.p.m. Ca.

Method.

To the 5 ml. of the Morgan's extract add 2 ml. of ammonium oxalate and shake. The white turbidity which forms after one minute can be matched in the specimen tubes or cells. (13·5 mm.) with prepared standards.

Magnesium.

Reagents.

1. Titan yellow .. .. 0·15 gm.
   Dissolve in 75 ml. of 95% ethyl alcohol and 25 ml. distilled water.
2. Hydroxylamine hydrochloric A.R. .. 2·0 gm.
   Sucrose A.R. .. .. 5·0 gm.
   Distilled water to .. .. .. 100 ml.
3. 2*N* Sodium hydroxide A.R. 8%

Method.

To 5 ml. of the Morgan's extract add 1 ml. of reagent (2). Add 3 drops of Titan yellow solution and 2 ml. of reagent (3). Make up to 10 ml. with distilled water. Match in the comparator with disc PMG using a 13·5 mm. cell.

Chloride.

Certain crops (*i.e.* red currant) are susceptible to the chloride ion and show symptoms which are difficult to distinguish from those caused by potash deficiency.

Reagents.

1. N/50 Silver nitrate A.R.

Method.

To the 5 ml. of the Morgan's extract add 2 ml. of silver nitrate solution.

A white turbidity indicates the presence of chloride ; the concentration can be matched with prepared standards of sodium chloride.

ESTIMATION OF TRACE ELEMENTS.

Preparation of Samples.

Plants growing on sharply acid soils (pH 4·0—4·5) should be tested for excess manganese. When estimating this element the same procedure (0·5 gm. tissue to 5 ml.) is followed as recommended for the extraction of major elements.

When a crop is suspected to be suffering from zinc toxicity, tests should be carried out for both zinc and iron (material with a high zinc content generally gives a high iron). These elements are extracted by taking the same amount of tissue (0·5 gm. for each test) and adding 1 ml. of hydrochloric acid. After 15 minutes add 10 ml. of distilled water and 2-3 drops of nitric acid, mix the contents by shaking, and pipette off 10 ml. The solution is then ready for the tests.

Reagents.

1. Morgan's reagent A.R.
2. Hydrochloric acid A.R. .. .. concentrated.
3. Nitric acid A.R. .. .. .. concentrated.

Manganese.

Reagents.

1. Trioxymethylene .. .. .. 20 gm. (Formaldoxime).
   Hydroxylamine sulphate .. .. 47 gm.
   Distilled water to .. .. .. 100 ml.
   Dissolve the reagents by boiling. Dilute 1 in 5 before use.
2. Sodium cyanide A.R. .. .. .. 20 gm.
3. 2*N* Sodium hydroxide .. .. 8%.

Method.

To the 5 ml. Morgan's extract add 1 ml. of reagent (2) and 6 drops of formaldoxime solution. Shake and make alkaline with reagent (3). The production of a wine coloration indicates the accumulation of manganese in the tissues. The colour can be matched with standards from stock solutions of manganese chloride.

Iron.

Reagents.

1. Ammonium thiocyanate A.R. .. 57 gm.
   Distilled water to .. .. .. 100 ml.
2. Amyl acetate A.R. and amyl alcohol A.R.
   Mix in equal volumes.

Method.

To the 5 ml. hydrochloric acid extract add 5 ml. of ammonium thiocyanate and 10 ml. of reagent (2). Reject the lower layer (aqueous) and transfer the upper layer into a 13·5 mm. cell and match in the comparator with disc KHB.

Zinc.

Reagents.

1. Cobalt acetate A.R. .. .. .. 1 gm.
   0·5 *N* Hydrochloric acid A.R. ... 100 ml.
2. Mercuric chloride A.R. .. .. 4 gm.
   Ammonium thiocyanate .. .. 4·5 gm.
   Distilled water to .. .. .. 100 ml.

Method.

To the 5 ml. hydrochloric acid extract add 0.5 ml. of reagent (1) and 5 ml. of reagent (2). Shake vigorously; the formation of blue crystals indicates the presence of zinc; the colour can be matched with prepared standards of zinc chloride.

SUMMARY.

1. An investigation of the suitability of chemical tissue tests for field work in conjunction with the "visual diagnosis" of mineral deficiencies was commenced at Long Ashton during the winter of 1943. A technique has been developed which can be used either in the laboratory or in the field.

2. Methods are described for the extraction and evaluation of nitrate, phosphate, potassium, calcium, magnesium and chloride, and under certain conditions for the trace elements, manganese, iron and zinc.

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THE APPLICATION OF RAPID CHEMICAL TESTS TO PLANT TISSUES IN THE DIAGNOSIS OF DEFICIENCIES OF MINERAL NUTRIENTS. PROGRESS REPORT I.

By D. J. D. NICHOLAS & J. O. JONES

In recent years interest has been focussed on the uses of quick chemical tests to assess the mineral status of plants. Some pioneer work on the application of these tests to soil extracts, as the source of plant nutrient supply, and also to plant tissues has been carried out by a number of American workers. Among the main contributors are Emmertt, Hester, Morgan and Thornton.

Some of the recognised methods used in the diagnosis of mineral deficiencies in plants are (*a*) Visual diagnosis, (*b*) Spray or injection of deficient plants, (*c*) Chemical analysis of plant material. During the 1944 season the tissue test method was examined with the view to its possible addition to this list. This method combines the advantages of time economy, simplicity of operation and a minimum of apparatus over the method of complete chemical analysis. However, its applicability to a variety of materials has yet to be established.

During 1944 chemical tissue tests have been carried out on fresh plant material with known deficiencies or grown with known nutrient treatment. The results obtained suggest that the method will be valuable for diagnostic purposes, although further experience will be necessary to enable standards to be fixed for various types of plants.

EXPERIMENTAL.

Plant Material Tested.

Details of the plant materials used are given in Table I. Special manurial treatments which had been applied appear later in conjunction with tissue test data.

TABLE I.

Centre and Date of Sampling	Crop	Variety	Nutritional Problem
A 7/9/44	1. Apple	Allington Pippin and Edward VII	Mg and slight K deficiency
31/7/44	2. ,,	Lane's Prince Albert	K and Mg deficiency
23/8/44	3. ,,	Cox's Orange Pippin	K deficiency
B 25/7/44	1. Apple	Laxton Superb	No outstanding problem; slight K deficiency
C 11/9/44	1. Apple	Bramley Seedling	
D 7/8/44	1. Apple	Cox's Orange Pippin	Mg deficiency
E	,,	,, ,, ,,	
F	,,	,, ,, ,,	
G	,,	,, ,, ,,	
A 31/7/44	4. Potato	Majestic and Edward	K and Mg deficiency
H 23/8/44	1. ,,	Majestic	K deficiency
A 2/10/44	5. Cauliflower	November	Mg deficiency
I 3/10/44 5/12/44	1. Tomato	Vetomold	Mg deficiency
A 1/8/44	6. Hop	Fuggle grown in sand culture	Ca, K, Mg & P deficiencies
	7. Sugar Beet	,,	,,
	8. Kale	Marrow Stem grown in sand culture	Ca, Mg & Fe deficiencies

Field Sampling Methods.

In sampling the above material certain precautions were observed. Random leaf samples were taken from a given treatment, and care was taken that leaves were comparable in position and size. The petioles were in all cases retained with the laminae. The sampling and subsequent chemical testing of plant material was carried out in the minimum of time. In view of the seasonal fluctuation in the mineral content of the leaves a record was kept of the date of sampling of each manurial experiment. In sampling, senescent leaves or leaves visibly affected with virus, fungi or insect pests were avoided, as their metabolism is likely to be abnormal.

Fruit Trees. Leaves comparable in maturity were chosen from near the base of the new leader growths.

Potato Haulms, Tomato Plants, Hop. Random leaf samples were taken from the mid stem region. Hence the plant parts were therefore more likely to be comparable as regards size and metabolic activity.

Cauliflowers and Sugar Beet. The first upright leaf was found to be the most satisfactory plant sample.

Preparation of Test Samples.

In most instances the plant petiole was taken for extraction purposes, instead of the laminae, because (*a*) it is less unwieldly, (*b*) the assessment of quantities taken is easier, (*c*) it usually contains less chlorophyll, flavones and anthocyanins.

In testing Brassicae and Sugar Beet parts of midribs of comparable girth were used.

The petioles were cut up into approximately 2 mm. discs by means of a sharp scalpel or blade. About 0·5 gm. was taken for each chemical test.

Extraction.

Time Factor. The time allowed for the extraction of nutrients from tissues was 15 minutes; this was kept constant throughout so that valid comparisons could be made between various tissue extracts.

Two extracting solutions have been recommended for use :—

1. *Morgan's Reagent.* Consisting of glacial acetic acid which is buffered by sodium acetate to a pH of 4·8. This is used for the extraction of most kations and anions from plant tissues.

2. *Hydrochloric Acid conc.* This is used for the extraction of iron and zinc; the latter when present at toxic concentrations.

5 ml. of Morgan's reagent was found to be adequate for the extraction of nutrients from 0·5 gm. of material, the extract being sufficient to test for one element. When a series of tests were contemplated bulk extracts were made in 50 ml. beakers of multiples of the above standard units. In all cases the tissue was allowed to steep in Morgan's Reagent for 15 minutes. 5 ml. of the extract was then pipetted out into clean specimen tubes depending on the number of tests to be undertaken. The chemical tests were applied to these extracts.

HCl extraction was used for iron and zinc. 1 ml. of HCl was pipetted on to 0·5 gm. of tissue and allowed to stand for 15 minutes, then 5 ml. of distilled water was added and the chemical test carried out on the extract.

Chemical Tests Used.

The elements and radicals tested in tissue extracts and the methods used are summarised in Table II. Initially most of these methods were taken from Stoughton and Fawcett's publication (3).

RESULTS.

The assessment of turbidity and colour was made mainly by eye, the following broad categories being adoped : High (H.), Medium (M.) and Low (L.). The use of a + or — sign with each of these was later introduced to subdivide these categories. Use was also made of the Lobivond Comparator, but this was limited by the fact that only magnesium, phosphate and nitrate discs were available. When using the comparator it was found convenient to dilute to a known volume. However, the figures in Table III report the concentration of nutrients in parts per million in the 5 ml. Morgan's extract.

Visual groupings agreed well with disc readings. Standards were made up for calcium and potassium and the unknown calcium and potassium turbidities were compared with these.

TABLE II.

CHEMICAL TESTS.

Extracting Soln. 1. Morgan's solution 2. HCl (Conc.)	Kations or Anions Tested	Reagents Used	Colouration or Turbidity Ranges	
			Minimum	Maximum
1	Potassium (K)	3 drops 35% sodium cobaltinitrite 2 mls. Isopropyl alcohol	Clear reddish brown soln.	Deep canary yellow turbidity
1	Calcium (Ca)	5 mls. Saturated solution of Ammonium oxalate	Colourless soln.	Greyish white turbidity
1	Magnesium (Mg)	3 drops 0·15% Titan Yellow 0·5 mls. 2% Hydroxylamine hydrochloride 0·5 mls. 5% Sucrose 8% Sodium hydroxide until alkaline	Straw yellow soln.	Salmon pink colouration
1	Manganese (Mn)	6 drops 10% Trioxymethylene sulphate 8% Sodium hydroxide until alkaline	Colourless soln.	Deep cherry colouration
2	Ferric Iron ($Fe^{''}$)	3 drops Nitric acid 5 mls. 20% Potassium thiocyanate 2 mls. Amyl alcohol	Colourless soln.	Blood red colouration
2	Zinc (Zn)	0·5 mls. 1% Cobalt acetate in 0·5 N HCl 5 mls. 9% { Mercuric Chloride Ammonium thiocyanate	Colourless	Accumulation of blue plate-like crystals
1	Nitrate (NO_3)	2 mls. 25% W/V phenoldisulphonic acid in sulphuric acid 10 mls. 10% Ammonia until alkaline	Colourless	Deep buff colouration
1	Phosphate (PO_4)	2 mls. 4% Ammonium molybdate 1 mls. 1% Hydroquinone 2 mls. Sodium carbonate 20% Sodium sulphite	Faint blue	Deep Medit: blue colouration
1	Chloride (Cl)	2 mls. $\frac{N}{50}$ Silver Nitrate	Colourless soln.	White turbidity

It should be noted that reading equivalents of the visual categories High, Medium and Low vary according to the type of plant under investigation. Apple and potato petiole extracts invariably have a low phosphate disc range (0—30 p.p.m.) for the three groupings, whereas those of most brassicae record 0—50 p.p.m.. Magnesium range appears to be more constant (0—8 p.p.m.)

for most plants studied in this report. Information relating to the possible range of kation and anion concentration was obtained before segregation into visual categories. Table III shows the relation between visual categories and chemical concentration of nutrients. The latter are expressed in parts per million in 5 ml. Morgan's extract and are applicable to most experimental material examined.

TABLE III.

VISUAL CATEGORIES AND CORRESPONDING TENTATIVE NUTRIENT CONCENTRATION. (p.p.m. in 5 ml. Morgan's extract).

Visual Categories	Calcium	Magnesium	Potassium	Brassica Phosphate	Fruit & Potato Phosphate
H	175	8	150	50	30
H—	150	7	125	40	25
M+	125	6	100	30	20
M	100	5	75	25	15
M—	75	4	50	15	10
L+	50	3	25	10	5
L	25	2	10	<10	<5
L—	<10	1	5	—	—

Care was taken to read the density of turbidity and intensity of colour soon after they were produced. It was found that the phosphate molybdate blue deepened on standing, and that initially Morgan's reagent alone gave a faint blue colouration with the phosphate reagents. Hence the Lovibond phosphate disc readings on tissue extracts may be too high. However, the prime concern was not absolute values as such but to ascertain the relative values. Tannins and other phenolic compounds leach out readily into extracts of petioles from fruit trees and mask the chemical results on standing. Hence the importance of a fairly quick assessment.

The results are tabulated so as to show readily any correlations between tissue test data, and (*a*) Manurial treatments, (*b*) Visual diagnosis data, (*c*) Data from chemical analysis of leaf laminae.

TABLE IV A.

Centre A. Expt. 1.

RELATION BETWEEN VISUAL SYMPTOMS, FULL CHEMICAL DATA AND TISSUE TEST DATA ON EDWARD VII APPLES UNDER DIFFERENT MANURIAL TREATMENTS.

Plot	Manurial Tr.	Visual Symptoms & number of Trees affected	As % Dry Matter Chemical Data on Leaves			Tissue Test Data on Petioles		
			MgO	K_2O	P_2O_5	Mg	K	P
Q	No manure	Nil	0·33	1·21	0·56	M—	M—	M
A+B	N.K.P. (Spring application)	Mg 4 trace 8 slight	0·30	2·0	0·57	M—	M+	M
C+D	N.K.P.(Summer application)	Mg 2 trace 10 slight	0·22	2·20	0·59	L+	M+	M
E+F	N.P.K.(Autumn application)	Mg 2 trace 6 slight	0·34	1·95	0·54	M	M+	M
G+H	N.P. (Spring application)	Mg 5 trace 2 slight	0·38	1·32	0·51	M	L+	M
I+J	,,	Mg 3 trace 4 slight K 4 trace	0·24	1·46	0·48	M—	M—	M
K+L	,,	Mg 2 trace 3 slight K 1 trace	0·37	1·68	0·57	M	M—	M

TABLE IV B.
ALLINGTON PIPPIN.

Plot	Manurial Tr.	No. of Trees with Mineral Deficiency Visual Symptoms	Chemical Data on Leaves			Tissue Test Data on Petioles		
			MgO	K_2O	P_2O_5	Mg	K	P
Q	as for Table IV A	K 2 trace	0·42	1·23	0·54	M	L+	M
A+B		Mg 1 trace	0·23	2·52	0·53	L+	M+	M
C+D		Mg 2 trace	0·20	2·49	0·49	M—	M+	M
E+F		Mg 2 trace	0·26	2·32	0·49	M	M+	M
G+H		Mg 1 trace	0·33	1·46	0·52	M	L+	M
I+J		Mg 2 trace	0·21	1·56	0·52	L+	M—	M
K+L		Mg 1 trace	0·36	1·65	0·56	M	M	M

The relevant features appear to be the following :—

(*a*) Plant material from A+B, C+D and E+F plots are higher in potash content than the other plots. Tissue tests and chemical analyses show good agreement.

(*b*) Q foliage is low in potassium : in the Allingtons a potash scorch was recorded. Tissue test results and visual data also record a shortage of potash in Edward I+J and K+L.

(*c*) All methods suggest an unsatisfactory magnesium status, around the threshold value for this deficiency. The agreement is again close for full chemical and tissue test data.

TABLE V.

Centre A, Expt. 2.

RELATION BETWEEN VISUAL SYMPTOMS, FULL CHEMICAL DATA AND TISSUE TEST DATA ON LANE'S PRINCE ALBERT APPLES UNDER DIFFERENT MANURIAL TREATMENTS.

Plot	Manurial Treatment	Visual Symptoms	Chemical Data on Leaves as % Dry Matter				Tissue Test Data on Petioles			
			CaO	MgO	K_2O	P_2O_5	Ca	Mg	K	P
A1	No Manure	Nil	2·33	0·35	1·58	0·51	M+	M	M	M+
A2		K scorch severe	2·92	0·42	0·95	0·75	H—	M	L+	H—
B1	Complete	Nil	2·19	0·29	2·15	0·44	M+	M	H—	M+
B2	Inorganic	Nil	2·38	0·30	1·74	0·49	M+	M	M	M
C1	F.Y.M.	Nil	2·15	0·33	1·74	0·44	M+	M	H—	M+
C2		Nil	2·24	0·40	1·48	0·48	M+	M	M	M
D1	Omit N	Mg trace	2·04	0·28	2·18	0·52	M+	M—	H—	M+
D2 (*a*)		Mg severe prior	2·30	0·38	1·96	0·61	M+	M	H—	M+
D2 (*b*)		to spraying	2·27	0·43	1·72	0·62	M+	M	H—	M+
E1	Omit P	Mg trace	2·08	0·26	2·20	0·48	M+	M—	H—	M
E2		Nil	2·21	0·30	1·78	0·53	M+	M	H—	M
F1	Omit K	K scorch severe	2·35	0·33	1·17	0·45	M+	M	L+	M
F2 (Good Soil)		K scorch medium	2·27	0·30	1·32	0·47	M+	M	M—	M

Plots B2, C2, D1, E2 and F1 have received a soil application of $MgSO_4$ at the rate of 4 cwts. per acre for 4 consecutive years.

D2 (*a*). Foliage was sprayed with 1% $MgSO_4$. A 2 % $MgSO_2$ spray was applied to the foliage on 2/5/44 and 3/6/44.

The agreement between visual symptoms, full chemical data and tissue test results was good. The salient points are the following :—

(*a*) *Calcium.* Although the full chemical data suggest that this constituent is high, the tissue test values are only M+. It may be that the latter value is too low and that it should be a high. In view of this discrepancy the calcium results will need revision.

(*b*) *Magnesium.* In plots D1 and E1, the magnesium content of the leaf laminae is low and corresponds to the tissue category M—. Agreement with visual symptoms is also close.

(*c*) *Potassium.* When visual symptoms of potash deficiency were recorded as in Plots A2, F1 and F2 the full chemical results varied between 1·32% and 0·95% K_2O and corresponding tissue test values were M— and L+. The agreement is again good.

(*d*) *Phosphate.* All methods indicate that there is no difference in phosphate status in these manurial plots.

TABLE VI.

Centre A. Expt. 3.

Relation between Visual Symptoms and Tissue Test Data on Cox's Orange Pippin Apples with Potash and no Potash Treatments under Grass and Arable Conditions.

Treatment	Visual Symptoms	Tissue Tests on Petioles				
		Ca	Mg	K	P	Cl.
1 N.P.KCl	Nil	M+	M	H—	M+	H
2 N.P.—Grass	Nil	M+	M	M+	M+	L
3 N.P.—Arable	Medium K scorch	M+	M	L	M+	L

Both methods show similar results for the potash status and the tissue test data reflect the chloride dressing in 1.

TABLE VII.

Centre B. Expt. 1.

The Relation between Visual Symptoms and Tissue Test Data on Laxton Superb Apples under different Manurial Treatments.

Plot	Treatment	Visual Symptoms	Tissue Tests on Petioles			
			Ca	Mg	K	P
	Arable Plots					
A	No K	Trace K scorch	M+	H—	M—	M—
B	No P	Nil { in previous years trace K scorch	M+	M+	M—	M
C	F.Y.M.	Nil { recorded	M+	M+	M—	M
D	Nil	Previous K scorch now nil	M+	M+	M—	M
E	No N	Pale foliage (Low N.)	M+	M+	M	M
F	N.P.K.	Nil	M+	M+	M	M
	Grass Plots					
G	N.P.K.	Nil	M+	M+	M+	M+
H	No N	Pale foliage (Low N)	M+	H—	M+	H—
J	Nil	Previous K scorch now nil	M+	H—	M+	H—
K	F.Y.M.	do.	M+	M+	M	M+

In previous years potash deficiency symptoms were recorded in Plots A, B, C, D ; however, this year only trace potash scorch was observed in A. The tissue test data indicate that the potash condition of the trees in these plots is still M—. It is noteworthy that the same treatment under grass gives a higher potash and phosphate status in the tree.

The agreement between visual observations and tissue test results is again close.

Centre C. Expt. 1.

TABLE VIII.

THE EFFECTS OF VARIOUS MAGNESIUM SULPHATE TREATMENTS ON MAGNESIUM DEFICIENCY IN BRAMLEY SEEDLING.

Manurial Treatment	Visual Data. Severity of Mg Deficiency	Chemical Analysis of leaves % Dry Matter				Tissue Tests Data on Petiole Extracts			
		CaO	MgO	K_2O	P_2O_5	Ca	Mg	K	P
No Treatment	Severe	2·10	0·13	2·84	1·09	H—	L	H	H
Previously injected. Leaves from non-injected branches	Med.-Severe	1·88	0·18	2·79	0·75	M+	L+	H	M+
Previously injected. Leaves from non-injected branches	Med.-Severe	2·18	0·18	3·10	1·14	H—	L+	H	H
Treated $MgSO_4$ (Soil application)	Medium	2·18	0·22	2·52	1·10	H—	M—	H	H
do.	Medium	1·95	0·23	2·56	0·91	H—	M—	H	H
do.	Med.-Severe	1·86	0·15	3·02	1·15	H—	L	H	H

The correlation between visual data, chemical analysis and tissue test results is again good.

The severe magnesium symptoms correspond to the lowest MgO figure 0·13%, and the tissue test result is in agreement with this value (L). The medium to severe marking corresponds to a higher chemical result (0·18% MgO) and agrees with a low + tissue test result. The medium visual marking agrees with the chemical data and an increase is also reflected in the magnesium tissue test (M—). The potassium and phosphate status are high throughout, and in this respect the two methods are in good agreement. The calcium status is high as recorded by both chemical methods.

Centres D.E.F.G.

TABLE IX.

THE EFFECTS OF VARIOUS MAGNESIUM SULPHATE TREATMENTS ON MAGNESIUM DEFICIENCY IN COX'S ORANGE PIPPIN.

	Treatment	Visual Data Severity of Mg Defic.	Chemical Analysis of Leaves as % Dry Matter		Tissue Test Data on Petiole Extracts	
			MgO	K_2O	Mg	K
D1	Nil	Severe	0·10	2·92	L	H—
	$MgSO_4$ (Soil application)	Medium-Severe	0·15	2·67	L+	H—
	$MgCO_3$ (do.)	Medium-Severe	0·18	2·29	L+	H—
E1	No $MgSO_4$	Medium-Severe	0·11	2·00	L	M+
	No $MgSO_4$ (Soil) but injected $MgSO_4$	Medium-Severe	0·10	1·96	L—	M+
	$MgSO_4$ (Soil) and injected $MgSO_4$	Medium-Severe	0·11	1·76	L—	M+
	$MgSO_4$ (Soil) and sprayed	Slight-Medium	0·17	2·23	L+	H—
F1	Control	Severe	0·08	2·16	L—	H—
	Mg treated sprayed	Slight Mg.	0·27	2·20	M—	H—
G1	No $MgSO_4$	Medium-Severe	0·13	2·56	L—	H—
	Mg treated sprayed	Medium	0·20	2·64	L+	H—

The agreement between the various methods is good. It appears that when severe visual symptoms are recorded the full chemical data give low magnesium figures (·08% MgO) and tissue test results L and L—. When magnesium sulphate has been applied by injection, or spray, or to the soil, both chemical methods indicate an increase in the tissues. Visual symptoms in F1 (treated) are slight ; the chemical data (·27% MgO) is higher than other plots and again the tissue test value is the highest recorded (M—).

It is interesting to note that the potassium status is H— in most cases. It is possible that this high potash content accentuates the severity of magnesium deficiency.

The agreement for all these methods is again close, and the results suggest that although magnesium sulphate has been applied in various ways, the deficiency has not been fully corrected.

TABLE X.

Centre A. Expt. 4.

Relation between Visual Observations, Chemical Analyses and Tissue Test Results on Potato (Majestic and Edward) from Manurial Plots.

Manurial Treatment		Visual Data	Leaf Chemical Analysis as % D.M. Majestic			Tissue Tests on Petiole Extracts					
						Majestic			Edward		
			MgO	K_2O	P_2O_5	Mg	K	P	Mg	K	P
A1	Nil	Slight K scorch	1·08	3·16	0·85	H—	M—	H	H—	L	M+
A2	,,	,,	1·21	3·01	0·81	H	M—	M+	H—	L	H—
A3	,,	,,	0·93	3·83	0·80	M+	L+	H—	H—	L+	H—
B1	F.Y.M.	Nil	0·85	6·23	0·90	M+	H	H	H—	M+	M+
B2	,,	,,	0·97	6·35	0·87	M+	H	M+	H—	M+	M+
B3	,,	,,	0·80	6·87	0·81	M+	M+	H—	H—	M+	M+
C1	N.P.K.	Nil	0·70	7·03	0·80	H—	H	M	M	M+	M+
C2	,,	,,	0·98	7·21	0·80	M+	H	M	H—	M	M+
C3	,,	,,	0·81	6·89	0·87	M+	H	H	H—	M	M+
D1	No N	Med. Mg chlorosis also Low N	0·37	6·36	0·76	L	H	M	L+	H—	M
D2	,,	Nil	0·67	6·54	0·67	M	H	M	M	M	M—
D3	,,	Med. Mg chlorosis	0·40	6·73	0·69	L+	H	M	L+	M	M—
E1	No P	Nil	0·66	7·63	0·66	M—	H	M—	M—	H—	M—
E2	,,	,,	0·95	7·21	0·56	M+	H	M—	H—	M	L+
E3	,,	,,	0·84	7·07	0·68	M+	H	M—	M	M	M—
F1	No K	Med. K scorch	1·24	2·01	0·79	H—	M—	H	H—	L+	H
F2	,,	,,	1·30	2·17	0·83	H	L+	M+	H—	L	H—
F3	,,	,,	0·92	1·86	0·82	H—	M	M+	M+	L	M+

The agreement between visual observations, chemical data and tissue test results is again close.

In treatments A and F where potash was not applied, visual symptoms of potash deficiency were recorded, and the chemical data and tissue test values for this element are much lower than in other treatments.

The low magnesium content of plants growing in plots D1 and D3 are confirmed by the two chemical methods and the visual method. The application of magnesium sulphate to Block 2 is reflected in the tissue test data, chemical data and by the absence of visual symptoms.

Although no phosphate deficiency symptoms were apparent in treatment E both chemical methods agree that the phosphate status is lower than in other treatments.

TABLE XI.

Centre H. Expt. 1.

THE RELATION BETWEEN VISUAL SYMPTOMS AND TISSUE TEST DATA ON POTATO (MAJESTIC) FROM MANURIAL TREATMENTS.

Manurial Treatment	Visual Symptoms	Tissue Test Data				
		Ca	Mg	K	P	Mn
1. LIMED GROUP. 1 ton per acre.						
No K	K scorch	H—	H—	L	M+	Trace
2 cwts. K per acre	Nil	H—	H—	M	M	Trace
4 cwts. ,,	,,	H—	H—	H—	M	Trace
6 cwts. ,,	,,	H—	H—	H	M	Trace
2. NON-LIMED GROUP. soil pH 5·3.						
No K	K scorch	M	H—	M—	M+	H
2 cwts. K per acre	Nil	M	H—	M	M	H
4 cwts. ,,	,,	M	H—	H	M	H
6 cwts. ,,	,,	M	H—	H	M	H

The limed group record a higher calcium tissue test value than the non-limed series.

When potash was not applied visual symptoms of this nutrient deficiency were recorded and agree with the L and M— tissue test results. The potassium tissue value bears a close relation to the amount of potash applied.

It is interesting to note the accumulation of manganese in the tissues from the non-limed group. This usually occurs when plants are growing under acid conditions.

TABLE XII.

Centre I. Expt. 1.

THE EFFECTS OF DIFFERENT $MgSO_4$ TREATMENTS ON THE CONTROL OF MAGNESIUM DEFICIENCY IN GLASSHOUSE TOMATOES.

Treatment	Visual Data				Tissue Test Data on Petiole Extracts							
$MgSO_4$ application rates	No. of plants showing Mg defic. symptoms out of 150 per plot				3/10/44				5/12/44			
	3/10/44		5/12/44		A		B		A		B	
Blocks	A	B	A	B	Mg	K	Mg	K	Mg	K	Mg	K
No $MgSO_4$	—	—	59	64	L+	M+	L+	M+	L—	M+	L—	M+
Liquid application of fertiliser spray	19	16	36	38	M—	M	M—	H—	L	M+	L	M+
5 cwts. per acre	12	14	42	35	M	M	M	H	L	M	L	M
10 cwts. ,,	8	6	16	23	M+	H—	H—	H—	M—	M	M—	M
15 cwts. ,,	8	9	20	29	M+	H—	M	H—	M—	M	M—	M
20 cwts. ,,	3	7	19	26	M+	H—	H—	H—	M—	M	M—	M
2½% spray rate	0	0	0	0	H—	M—	H—	H—	M+	M	M+	M

There appears to be good agreement between the number of plants affected and Mg tissue test assessment. The medium tissue test level may indicate the threshold value of this constituent and is usually accompanied by the appearance of visual symptoms.

TABLE XIII.

Centre A. Expt. 5.

RELATIONS BETWEEN VISUAL SYMPTOMS AND TISSUE TEST RESULTS ON CAULIFLOWERS FROM MANURIAL PLOTS.

Manurial Treatment 3 blocks	% plants showing Mg defic. symptoms		Tissue Test Data on Midribs				
		Average for 3 blocks	Ca	Mg	K	P	Cl
A1	5		H—	M	M+	H—	M
A2 F.Y.M.	14	10	H—	M	M+	H—	M—
A3	12		H—	M+	M+	H—	M—
B1	10		H—	M	M	H—	M—
B2 F.Y.M. + N	11	10	H—	M	M	H—	M—
B3	11		H—	M+	M+	H—	M—
C1	28		H—	M—	M—	M	M—
C2 Veg. Compost + N	25	26	H—	M+	M+	M	M—
C3	24		H	M—	M	M	M—
D1	42		M	M—	M	M—	M—
D2 N.P.K.	27	35	H—	M—	M+	H—	M—
D3	36		H—	M—	M	H	M—
E1	34		H—	M—	M	H—	M—
E2 N.P.K.	26	34	H—	M—	M+	M+	M—
E3	41		M+	L+	M	H	M
F1	21		H—	M	M	M+	H
F2 N.P.K. (Potash Salts)	20	21	H—	M+	M+	M+	H
F3	21		H—	M+	M+	H—	H
G1 Sewage sludge-	5		M	M+	M+	H—	M—
G2 Straw Compost	9	7	H—	M+	M+	H	M—
G3	8		H—	M+	M+	H	M—
H1	5		M	M+	M+	M+	M—
H2 N.P.K. + $MgSO_4$	8	8	H—	M+	M+	H—	M—
H3	11		H—	M+	M+	H	M—

There is a fair agreement between the number of plants affected and magnesium tissue test data. However, representative sampling of a hundred large leaved plants is difficult in view of the fact that only 0·5 gms. of midrib is required for each chemical test. Hence it is advisable to assess the plots visually and choose plants that are representative of the visual marking.

The interesting features are :—

(*a*) The severity of magnesium deficiency is reflected in the tissue test information ; treatments G + H have the lowest number of plants affected, with the highest chemical category for magnesium M+. Treatments E and F have the lowest Mg value and highest % affected.

(*b*) The high chloride content recorded in treatment F is in agreement with the potassium chloride treatment.

TABLE XIV.

Centre A. Expt. 6.

Relation between Visual Symptoms and Tissue Test Results on Hop Grown in Sand Culture under known Nutrient Treatemnts.

Treatment	Visual Symptoms	Tissue Test Data			
		Ca	Mg	K	P
1. Complete Nutrient	Nil	M	M	H—	M
2. Compost	Probable P defic. symptoms, also low Ca symptoms	L	M	H—	L+
3. 2 × nitrogen level of (1)	Nil	M+	M+	M	M—
4. ¼ N level of (1)	Pale foliage (Low N)	L+	M—	H—	M
5. 2 × P level of (1)	Nil	H	M	M+	H—
6. ⅓ P level of (1)	Brown peppering effect				
	Probable P defic. symptoms	M+	M	M	L
7. 2 × K level of (1)	,,	M+	M	H—	L+
8. No K	Potash edge scorch	M—	M	L	M—
9. No Ca	Ca defic. symptoms	L	M—	M—	M—
10. No Mg	Mg chlorosis	M—	L	M+	M+
11. No trace elements	Probable P defic. symptoms	H	M+	L+	L+

When nutrients were omitted from the culture as in 8, 9 and 10 visual deficiency symptoms were recorded and the tissue test values for the minerals omitted were low. The agreement is close.

The appearance of probable phosphate deficiency symptoms in 2, 6, 7 and 11 is confirmed by a low tissue test value for phosphate. In 2, where calcium deficiency was diagnosed, the tissue test value is low for calcium.

TABLE XV.

Centre A. Expt. 7.

The Relation between Visual Diagnosis and Tissue Test Values on Sugar Beet Grown under known Nutrient Conditions.

Treatments	Visual Diagnosis	Tissue Tests				
		Ca	Mg	K	P	NO_3
Complete	Nil	H—	H—	H—	H—	H—
No N	N defic.	H—	M—	H—	H—	L
No K	K defic. edge leaf scorch	H—	H—	L	H—	H—
No P	P defic.	H—	H—	H—	L	H—
No Ca	Ca defic.	L	H—	H—	H—	H
No Mg	Mg chlorosis	H—	L	H—	H—	H—

Tissue tests confirm the nutrient treatment and are in accordance with the visual observations. When a given nutrient is not given to the plants,

tissue test results for that particular element are low. The visual observations agree closely with chemical values on the tissues, a noteworthy feature is the medium — Mg status recorded by all methods for plants growing under depleted nitrogen conditions.

TABLE XVI.

Centre A. Expt. 8.

Correlation between Visual Diagnosis and Tissue Test Data on Marrow Stem Kale from known Nutrient Cultures.

Treatments	Visual Data	Tissue Test Data		
		Ca	Fe″′	Mn
Complete	Nil	M+	H—	Trace
No Iron	Fe chlorosis	H—	L+	Trace+
No Calcium	Ca defic. symptoms and chlorosis in younger leaves (probably Fe)	L	L+	M

In the no-iron culture iron deficiency symptoms were recorded and this agrees with the tissue test value (L+). In the no-calcium treatment deficiency symptoms of this nutrient were observed, and this is again reflected by an L calcium tissue test result. It was observed that iron deficiency symptoms appeared in plants from this treatment; this was confirmed by an L+ iron value in the plant extract.

DISCUSSION.

From the foregoing tables it will be seen that there is a fair degree of correlation between visual symptoms, manurial treatment and tissue test data. Invariably the tissue test results agree with the severity of the deficiency symptoms. It seems that visual symptoms of potassium or magnesium appear when these particular kations record about M— on the tissue extracts. This category may well be critical for calcium, phosphate and nitrate with the onset of deficiency symptoms, although the data are not so complete. It has been noted that the calcium tissue test value for fruit trees may be too low as compared with the full chemical results (Table V). In view of this discrepancy the calcium tissue test values need revision.

The agreement between the full chemical data and tissue test values can be close. Both methods detect mineral deficiencies in plants and usually indicate the severity of nutrient shortage.

In Table XVII are set out tentative levels of comparison between the full chemical data and tissue test assessment, taken from the apple series.

TABLE XVII.

Tentative Levels of Comparison between the Full Chemical Data and Tissue Test Values for Apple.

Nutrient Levels in Tissues.	Leaf Laminae Analyses as % Dry Matter			Tissue Test Assessment on Petiole Extracts.		
	K_2O	MgO	P_2O_5	K	Mg	P
High	2·0	0·50	1·0	150 p.p.m.	8 p.p.m.	20 ppm
Medium	1·5	0·35	0·50	75 ,,	5 ,,	10 ,,
Low	0·90	0·15	—	10 ,,	2 ,,	5 ,,

Much work remains to be done on different types of plants under varied nutrient conditions before tables of this kind can be standardised. Problems relating to the effect of (*a*) time of sampling, (*b*) interfering substances on the extraction of kations and anions from tissues must also be investigated.

CONCLUSIONS.

The tissue test method has proved useful in the diagnosis of mineral nutrient deficiencies in plants. The correlation between this method, manurial treatments and visual diagnosis is good. There is agreement, too, between the full chemical data and tissue test values ; both methods usually indicate the nutrient condition of plants. The results obtained suggest that the tissue test approach will be valuable for diagnostic purposes, although furthur experience is essential to solve certain problems. These problems include (a) the best time for sampling plant material, (*b*) the effect of interfering substances on the extraction of kations and anions from tissues, (*c*) fixing of nutrient standards for various types of plants. However, preliminary results have justified its inclusion in the scheme of methods for the diagnosis of mineral deficiencies.

SUMMARY.

1. Test materials from known manurial plots and known nutrient treatments are listed.

2. The field sampling methods and the preparation of test samples are described.

3. Details of the extraction of kations and anions from plant petioles by means of Morgan's Reagent or hydrochloric acid are given.

4. Tissue tests results are tabulated so that correlation with manurial treatment, visual data and full chemical analysis is indicated.

5. The results suggest that tissue tests are of value for diagnostic purposes. Further experience is required in order to fix standards for various plants.

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THE MINERAL ELEMENT CONTENT OF FLAX STRAW FROM EXPERIMENTAL CENTRES.

SEASON 1943

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In the early part of 1943 extensive field trials were laid down at various centres to ascertain the probable mineral requirements of flax. These centres were chosen because susceptible crops had shown acute deficiency symptoms when grown in these areas. Details are given in Table I of the location, soil type and occurrence of deficiency symptoms in previous crops.

TABLE I.

THE LOCATION, SOIL TYPE, AND VISUAL DEFICIENCY SYMPTOMS IN DIFFERENT CROPS AT THE EXPERIMENTAL CENTRES.

Index	Centres	Soil Type	Previous Crops	Recognised Visual Nutrient Deficiencies
A	Long Ashton Research Station	Drift over Keuper Marl	Potatoes	N, P, K, Mg
B1	Bristol Market Garden Areas	Pennant Grit	Variety of Market Garden Crops	Mn
B2	,, ,,			
C	Cannington, Somerset	Drift over Keuper Marl	Sugar Beet, Mangolds and Swedes	Mn, B
D	Ross-on-Wye, Hereford	Old Red Landstone, Light calcareous loam of the Ross Series	Sugar Beet	B
E	Wilton, Salisbury	Chalk with thin overwash	Sugar Beet, Mangolds and Marrow Stem Kale	K, B
F	Newnham Bridge, Worcester	Coal Measures	Wheat, Oats, Barley	P

Experiments at Centres A and F were laid down to study the effect of the shortage of major elements on the yield of flax, whereas those at B, C, D and E were primarily concerned with the effect of trace element deficiencies on yields and quality of the fibre. The only significant response occurred at Centre F when phosphate was applied. However, here even in the absence of phosphatic manuring 67 cwts. per acre of dry flax was obtained.

Material Analysed. Mature flax straw was sampled at the time of harvest from the experimental plots. Care was taken that the straw was deseeded. When treatments were in duplicate as in Centres C, D, E and F, one block only was sampled for chemical analysis. Large samples were taken from each plot, dried at 98° C. for three days, chaffed and subsequently milled to a fine powder. The samples taken for analysis were therefore quite representative of each treatment.

Chemical Methods. The major elements, calcium, magnesium, potassium and phosphate, were estimated by the well-known standard methods, directly on the chloride ash solution. They are expressed on a percentage dry matter basis.

The trace elements, iron, manganese, and boron, were estimated colorimetrically; use was made of the Spekker Absorptiometer, and the results expressed as parts per million on dry matter.

Iron. This constituent was estimated as ferric iron by means of the thiocyanate method described by McFarlane. A calibration diagram was prepared with known standards and a combination of light blue and green filters. The calibration is linear for the concentrational range ·005 mgs. to 0·5 mgs. per 10 mls.

Manganese. This element was determined by the usual potassium periodate method with the subsequent oxidation of Mn. compounds to potassium permanganate. This colouration was determined by means of the Spekker using green filters. The calibration range from ·05 mgs. to 2 mgs. per 100 mls. bears a linear relationship to readings.

Boron. The quinalizarin method was found to be the most convenient. There appears to be a linear relationship between drum readings over the range ·0005 mgs. to ·0045 mgs. per ml., using red filters and blank determinant in the left-hand water cell.

Centre A.

The soil in this region may be described as a sandy loam containing calcium carbonate. The plots used formed part of a series of deficiency plots which had been subjected to manurial treatments since 1927. Details of the treatments appear in Table II.

TABLE II.

MANURIAL TREATMENTS.

Treatment	A	..	No manure
,,	B	..	10 tons of stable manure
,,	C	..	4 cwts. nitrate of soda, 3 cwts. superphosphate, 3 cwts. sulphate of potash
,,	D	..	3 cwts. superphosphate, 3 cwts. sulphate of potash (N omitted)
,,	E	..	4 cwts. nitrate of soda, 3 cwts. sulphate of potash (P omitted)
,,	F	..	4 cwts. nitrate of soda, 3 cwts. superphosphate (K omitted)

The treatments were in triplicate and to Block 2 magnesium sulphate at the rate of 4 cwts. per acre was applied in 1939 and 1940 to counteract symptoms of Mg deficiency which appeared in black currants and potatoes in treatment B (slight), C, D and E (all severe). Potassium deficiency symptoms were also severe in plots A and F. Also nitrogen and phosphate shortage were apparent in plots D and E respectively.

Visual deficiency symptoms were recorded in flax early in the season, when trace nitrogen and a trace potassium symptoms were apparent.

The analytical data appear in Table III. The major elements are expressed as the oxides on a percentage dry matter basis. The trace elements Fe, Mn and B are expressed in parts per million.

The salient points arising out of Table III are :—

(1) *Calcium.* This constituent appears to be adequate in flax straw material irrespective of treatments.

CENTRE A.

TABLE III.

Chemical Analysis of Flax Straw.

Treatment	No Manure			F.Y.M.			N.P.K.			No N			No P			No K		
	A1	A2*	A3	B1	B2*	B3	C1	C2*	C3	D1	D2*	D3	E1	E2*	E3	F1	F2*	F3
Ash as % Dry Matter ..	2·91	2·85	2·78	2·99	2·77	2·72	2·82	2·86	3·07	3·40	2·99	3·39	3·27	3·67	3·20	3·72	2·44	2·86
CaO as % Dry Matter ..	0·94	0·90	0·86	0·59	0·62	0·59	0·62	0·71	0·65	0·76	0·57	0·68	0·55	0·60	0·50	0·96	0·90	0·88
MgO ,, ..	0·12	0·13	0·10	0·10	0·12	0·10	0·10	0·11	0·10	0·08	0·11	0·08	0·10	0·12	0·08	0·10	0·12	0·10
K_2O ,, ..	0·77	0·72	0·70	1·30	1·20	1·25	1·38	1·30	1·41	1·15	1·16	1·20	1·19	1·15	1·34	0·79	0·76	0·71
P_2O_5 ,, ..	0·18	0·16	0·18	0·20	0·18	0·21	0·18	0·19	0·23	0·25	0·22	0·28	0·20	0·24	0·23	0·20	0·24	0·17
Fe in p.p.m.	100	72	110	87	89	78	88	110	80	69	118	100	84	103	110	76	108	110
Mn ,, ...	12	10	7	14	10	10	10	14	10	10	15	10	10	8	8	14	8	10
B ,, ...	20	12	14	16	12	14	20	20	20	20	20	14	20	20	22	21	14	17

* $MgSO_4$ applied to all plots in Block 2.

(2) *Magnesium.* Values are low throughout yet there were no visual symptoms of magnesium deficiency. It is noteworthy that Block 2 plants have a slightly higher magnesium content in accordance with soil application. Even so Mg values are below those of other centres.

(3) *Potassium.* Low values are recorded in Plots A and F where potash was not applied.

(4) *Phosphate.* This anion appears to be adequate throughout with no low valuation in Plot E (omitting phosphate).

(5) *Iron.* The total iron results are high. In other calcareous centres about 50 p.p.m. appears to be adequate. It may be that there is a relation between total iron and soil organic matter, as the accumulation of this constituent does not seem to be governed by soil pH.

(6) *Manganese.* The manganese content is low (8—14 p.p.m.), yet there were no characteristic visual symptoms of this deficiency. The high organic content of the soil and the free lime present probably account for the shortage of this nutrient in the flax material.

(7) *Boron.* There appears to be an adequate boron content in all the plants irrespective of treatment.

Centres B1 and B2.

The soil at these adjacent centres is composed of a fine sandy loam developed on the Pennant Grit. It contains a high proportion of comminuted organic matter and has a high content of calcium carbonate.

Practically every crop grown in these two adjacent centres developed severe manganese deficiency symptoms. In 1943 a variety of market garden crops, including legumes, was grown here. Invariably plants showed acute manganese deficiency symptoms. Wheat, oats and barley failed completely because of manganese shortage.

The analytical results are presented in Table IV.

The data indicate that :—

(1) The major element nutrition is sufficient in both centres.

(2) *Iron.* The iron content is comparable to Centre A. In this connection it is interesting to note that the soil is high in organic matter.

(3) *Manganese.* This nutrient is very low (6 and 7 p.p.m.). However, there were no visible signs of this deficiency.

(4) *Boron.* Although the soil is calcareous, the uptake of this element seems to have been sufficient.

Centre B.

TABLE IV.

Chemical Analysis of Flax Straw.

	B1	B2
Ash as % Dry Matter	3·88	4·32
CaO as % Dry Matter	0·86	0·82
MgO „	0·23	0·26
K_2O „	1·42	1·62
P_2O_5 „	0·18	0·23
Fe in p.p.m.	118	89
Mn „	6	7
B „	13	10

CENTRE C.

TABLE V.

CHEMICAL ANALYSIS OF FLAX STRAW.

Treatment	Nil	B	N.B	K.B	N.K.B	Mn	N.Mn	K.Mn	N.K.Mn	B.Mn	N.B.Mn	K.B.Mn	N.K.B.Mn
Ash as % Dry Matter ..	3·24	4·06	3·51	3·62	4·40	3·60	3·42	3·94	3·76	3·15	4·10	3·90	3·93
CaO as % Dry Matter ..	0·73	0·80	0·78	0·78	0·96	0·86	0·78	0·73	0·87	0·70	0·76	0·71	0·70
MgO ,, ..	0·16	0·17	0·16	0·15	0·15	0·16	0·15	0·15	0·14	0·15	0·16	0·16	0·17
K_2O ,, ..	1·20	1·21	1·25	1·57	1·47	1·23	1·20	1·65	1·68	1·20	1·52	1·58	1·61
P_2O_5 ,, ..	0·24	0·21	0·24	0·23	0·26	0·21	0·27	0·26	0·26	0·24	0·26	0·26	0·26
Fe in p.p.m.	44	47	40	46	44	46	42	37	35	41	42	46	48
Mn ,, ...	7	7	8	8	7	22	25	21	26	22	27	26	28
B ,, ...	6	8	9	8	8	6	5	5	6	10	11	11	10

Centre C.

The soil at this centre is a thin drift with gravel at variable depths over Keuper Marl. The topography was very even, and there appeared to be no noteworthy soil variation.

A soil sample taken before the application of fertilisers on analysis gave the following figures :—Lime, 5% ; available phosphoric acid, ·0129% ; available potash, ·0074%. The potash soil figure is rather low.

During the 1942 season, sugar beet, mangolds and swedes grown at this centre gave only a moderate yield and visual symptoms of acute boron deficiency and of manganese deficiency appeared in sugar beet.

The plots at this centre were put down on a very flat and even piece of land. The treatments were randomised within the block, and 2 blocks were incorporated in this experiment. The rotation per block was as follows :—

O	..	1	B	..	5	Mn	..	9	B.Mn	..	13
N	..	2	N.B	..	6	N.Mn	..	10	N.B.Mn	..	14
K	..	3	K.B	..	7	K.Mn	..	11	K.B.Mn	..	15
N.K	..	3	N.K.B	..	8	N.K.Mn	..	12	N.K.B.Mn	..	16

Treatment. The fertiliser treatments were applied on 18.3.43 at the following rates :—

Nitrogen	..	1 cwt. of sulphate of ammonia per acre.
Potassium	..	1½ cwts. of muriate of potash per acre.
Boron ..	..	20 lbs. borax per acre.
Manganese	..	40 lbs. manganese sulphate per acre + 1 spraying 2% manganese sulphate on 26.5.43.

The chemical data relating to the flax straw from this centre are presented in Table V.

The salient features are :—

(1) *Major elements.* Calcium, magnesium, potassium and phosphate are adequate throughout.

(2) *Iron* is about average for the series but lower than at Centres A and B.

(3) *Manganese.* When this nutrient is not applied the level in the tissues is very low (7 p.p.m.). However, as in Centre A and B no symptoms were evident. Manganese treated plots show a marked increase over non-treated plants.

(4) *Boron.* This element is low (6 p.p.m.), but on treating with borax there is a slight but definite uptake by the flax plants. However, even this value is much below those of Centre A (20 p.p.m.).

Centre D.

The soil at this centre is composed of a light sandy calcareous loam of the Ross series derived from the Old Red Sandstone. The ground is even and no appreciable soil variation could be detected over the area. A soil analysis prior to treatment was as follows :—Lime, 10% ; available phosphoric acid, ·0157% ; available potash, ·0139%.

The potash and phosphate status is good and there is abundant lime in the soil.

In 1942 sugar beet on this plot showed acute boron deficiency symptoms with a substantial loss of crop. However, no visual symptoms that could be attributed to boron deficiency appeared in flax.

The layout of the experiment in 2 blocks, notation and fertiliser treatment are identical with Centre C. One block of treatments was sampled for chemical

CENTRE D.

TABLE VI.

Chemical Analysis of Flax Straw.

Treatment	Nil	B	N.B	K.B	N.K.B	Mn	N.Mn	K.Mn	N.K.Mn	B.Mn	N.B.Mn	K.B.Mn	N.K.B.Mn
Ash as % Dry Matter ..	4·60	4·10	4·40	4·67	4·58	4·06	4·30	5·10	4·62	4·41	4·92	4·31	5·76
CaO as % Dry Matter ..	0·73	0·67	0·70	0·71	0·74	0·84	0·67	0·78	0·65	0·67	0·81	0·78	0·84
MgO „ ..	0·17	0·19	0·18	0·17	0·16	0·17	0·17	0·19	0·16	0·17	0·19	0·16	0·19
K_2O „ ..	1·70	1·68	1·65	2·05	1·97	1·66	1·70	2·14	1·92	1·70	1·68	1·90	2·30
P_2O_5 „ ..	0·16	0·15	0·17	0·18	0·18	0·18	0·19	0·20	0·18	0·16	0·16	0·17	0·17
Fe in p.p.m.	53	53	50	50	56	50	52	57	66	64	66	65	58
Mn „	27	28	30	31	36	39	30	33	38	36	35	36	38
B „	7	11	12	14	12	7	7	7	8	11	12	12	11

analysis on 19.7.43. Fertiliser application was on 24.3.43, and subsequent spraying of manganese treated plots 27.5.43 (as in Centre C).

The chemical data appear in Table VI.

Points of interest are the following :—

(1) *The major elements.* Calcium, magnesium, potassium and phosphate are adequate throughout, although the phosphate values are lower than at Centre A.

(2) *Iron* status is probably average for flax straw and is comparable to that of Centre C.

(3) *Manganese.* Although the soil is calcareous the Mn content of the straw is at a nutritional optimum (30 p.p.m.), whereas that of Centre C non-treated plots is 7 p.p.m.

(4) *Boron.* This element is low in flax samples from the non-borax treated plots (7 p.p.m.), whereas boron treated plots record 12 p.p.m. These are comparable to Centre C results.

Centre E.

The soil at this centre is derived from a thin drift overlying chalk, and contains chalk and clay fractions with some flinty inclusions. Soil analysis is as follows :—Lime, 10% ; available P_2O_5, ·0057% ; available K_2O, ·008%. The available phosphate and potash are low in this soil, whereas the calcium carbonate content is very high.

In 1941 and 1942 crops of sugar beet, mangolds and marrow stem kale were all severely affected by boron deficiency. There was also a trace of potash deficiency in some susceptible crops. Flax also showed symptoms of K deficiency in patches.

The notation, treatment and layout was comparable to that of Centre C.

The chemical data on mature flax straw appear in Table VII.

The following observations are made from the chemical results :—

(1) *Major elements.* Calcium, magnesium and phosphate are adequate throughout. However, potassium is low, 1·0% K_2O, and at this level a trace of potash deficiency symptoms were recorded. On the application of potash the K_2O level increases to 1·5%.

(2) *Iron.* These figures compare favourably with those of Centres C and D. This status may be described as average.

(3) *Manganese.* Although the soil is calcareous the uptake of this element has been satisfactory, and is therefore comparable to Centre D but much higher than Centre C.

(4) *Boron.* As in the previous 2 centres this constituent is low (6 p.p.m.), but there is an increase when borax has been applied (11 p.p.m.).

Centre F.

The experiment at this centre was laid out on rather uneven ground. Prior to ploughing in 1942 this land was a very rough sheep pasture. The soil is derived from the Coal Measures being a greyish brown clay loam.

Soil analysis taken early in 1943 is as follows :—Lime, nil ; moisture, 2·379% ; organic matter, 7·605% ; available P_2O_5, ·004% ; available K_2O, ·0148% ; pH, 5·22.

The soil phosphate content is very low and the soil contains no free lime.

The area is an example of extreme phosphorus deficiency. In 1942 wheat, oats and barley without phosphate treatment failed entirely. However, no visual symptoms of phosphate deficiency were apparent in the flax.

CENTRE E.

TABLE VII.

Chemical Analysis of Flax Straw.

Treatment	Nil	B	N.B	K.B	N.K.B	Mn	N.Mn	K.Mn	N.K.Mn	B.Mn	N.B.Mn	K.B.Mn	N.K.B.Mn
Ash as % Dry Matter ..	3·61	3·72	3·83	4·23	3·77	3·84	4·08	3·71	3·72	4·03	3·40	3·81	3·81
CaO as % Dry Matter ..	0·93	0·85	0·90	0·85	0·93	0·96	0·93	0·76	0·87	0·93	0·92	0·95	0·80
MgO ,, ..	0·21	0·20	0·18	0·26	0·19	0·25	0·20	0·22	0·20	0·23	0·18	0·19	0·18
K_2O ,, ..	1·06	1·18	1·05	1·58	1·50	1·06	1·10	1·53	1·47	1·09	1·00	1·51	1·46
P_2O_5 ,, ..	0·22	0·21	0·22	0·23	0·20	0·23	0·20	0·24	0·18	0·20	0·15	0·20	0·15
Fe in p.p.m.	60	61	61	65	62	65	60	51	49	61	51	58	54
Mn ,, ...	41	42	48	44	46	49	49	51	48	48	48	42	40
B ,, ...	6	10	13	10	10	6	7	7	6	11	10	11	12

The experiment was laid out in two blocks and was primarily designed to test the effect of phosphate manuring on flax. Phosphate application gave a significant increase in yield at this centre. One block only was sampled for chemical analysis when harvesting was in progress.

Notation.

0	..	Control	8	..	Salt
1	..	N	9	..	N.S.
2	..	P	10	..	P.S.
3	..	K	11	..	K.S.
4	..	N.P.	12	..	N.P.S.
5	..	N.K.	13	..	N.K.S.
6	..	P.K.	14	..	P.K.S.
7	..	N.P.K.	15	..	N.P.K.S.

Treatment. The rates of fertiliser application were as follows :—

Sulphate of ammonia	.. .. ..	1 cwt. per acre.
Superphosphate	.. ..	3 cwts. per acre.
Muriate of potash	.. .. ..	1¼ cwts per acre.
Agricultural salt	.. .. ..	3 cwts. per acre.

The fertilisers were applied on 5.4.43 and sampling for chemical analysis 17.8.43.

Results are tabulated in Table VIII.

The chief features arising out of the chemical results are :—

(1) The *calcium* status is low throughout, practically all determinations at this centre are below 0·50% CaO. These are the lowest calcium figures of the experimental series.

(2) The *magnesium* content of the straw is adequate and varies from ·14% to ·22% MgO.

(3) The *potassium* figures are about average.

(4) *Phosphate.* This constituent is very low in non-treated plots ·10% P_2O_5. This is the lowest figure recorded in the whole range of analysis. There is however a significant response in most cases to phosphatic manuring, doubling phosphate content in treated plants in most cases (·20% P_2O_5). However, no visual symptoms of phosphate were recorded on any plot.

(5) *Iron.* Total iron may be described as average compared with the figures at Centres C, D and E. It is interesting to note that the latter centres are calcareous. whereas this centre has no free lime in the soil. However, iron does not seem to accumulate rapidly at a soil pH of 5·22.

(6) *Manganese.* These values are significantly higher than those of other centres. As a rule manganese accumulates in the tissues very rapidly when plants grow under acid conditions, and flax conforms to that general rule. It is noteworthy that in most cases there is a significant uptake of this kation when salt is incorporated in the soil dressing. The highest manganese figure recorded is 183 p.p.m. in the phosphate salt treatment.

(7) *Boron* content of the straw is higher than that of Centre C, D and E and is comparable to Centre A determinations.

General Discussion.

It will be noted that in susceptible crops from all the centres listed in Table I acute mineral deficiency symptoms were evident. In many cases the nutrient levels were so low that most plants failed to thrive. However, flax subsequently grown on these plots appeared to be unaffected except for probable low potash symptoms where potash was not applied in Centres A and E.

CENTRE F.

TABLE VIII.

Chemical Analysis of Flax Straw.

Treatment	Nil	N	P	K	N.P	N.K	P.K	N.P.K	Salt	N.S	P.S	K.S	N.P.S	N.K.S	P.K.S	N.P.K.S
Ash as % Dry Matter	3·38	3·31	3·76	3·58	3·54	3·12	3·25	3·08	3·62	3·45	3·48	3·96	3·57	3·98	3·55	3·88
CaO as % Dry Matter..	0·42	0·40	0·46	0·45	0·41	0·43	0·41	0·41	0·46	0·44	0·40	0·45	0·46	0·52	0·47	0·42
MgO ,, ..	0·14	0·16	0·17	0·15	0·15	0·14	0·14	0·15	0·16	0·15	0·17	0·22	0·19	0·16	0·19	0·20
K_2O ,, ..	1·45	1·47	1·42	1·81	1·41	1·75	1·68	1·83	1·50	1·44	1·35	1·85	1·69	1·71	1·62	1·73
P_2O_5 ,, ..	0·10	0·12	0·19	0·13	0·18	0·12	0·19	0·20	0·14	0·14	0·18	0·13	0·20	0·13	0·20	0·20
Fe in p.p.m. ..	45	42	53	47	55	47	47	39	38	35	41	43	51	58	48	45
Mn ,, ..	63	76	82	63	85	97	81	105	125	148	183	141	133	125	116	137
B ,, ..	20	21	18	15	17	21	16	17	17	18	17	21	17	20	20	19

In Table IX the mean K_2O figures are recorded for Centres A and E, for plots where (*a*) potash was not applied, (*b*) potash was applied with corresponding visual observations.

TABLE IX

THE MEAN POTASSIUM CONTENT OF FLAX FROM TREATED AND NON-TREATED POTASH PLOTS AT CENTRES A AND E WITH CORRESPONDING VISUAL MARKING.

Centre	Treatment	Visual Marking	Mean of Plots K_2O as % Dry Matter
A	No K	Probable K deficiency symptoms	0·70
„	K	Nil	1·25
E	No K	Probable K deficiency symptoms	1·0
„	K	Nil	1·50

It seems, therefore, that ·70% of K_2O may well be approaching the threshold value for this constituent with the onset of potash deficiency visual symptoms.

In Table X are listed for each of the six centres the lowest level for each particular nutrient; also visual observations on previous cropping and on flax.

TABLE X.

VISUAL DEFICIENCY SYMPTOMS OF SUSCEPTIBLE CROPS AND FLAX FROM CENTRES A—F WITH CORRESPONDING LOWEST NUTRIENT LEVELS IN FLAX STRAW.

Centre	Visual Deficiency Symptoms		Lowest Nutrient Levels in Flax Straw						
	Susceptible Crops	Flax	As % Dry Matter CaO	MgO	K_2O	P_2O_5	In parts per million Fe	Mn	B
A	K.Mg.P.N	Trace K	0·60	0·10	0·70	0·17	69	8	12
B1 & 2	Mn	Nil	0·82	0·23	1·42	0·18	89	6	10
C	Mn.B	Nil	0·70	0·14	1·20	0·21	35	7	5
D	B	Nil	0·65	0·16	1·65	0·15	50	27	7
E	K.B	Trace K	0·8	0·18	1·0	0·15	49	40	6
F	P	Nil	0·40	0·14	1·35	0·10	35	63	15

From the foregoing table it is evident that although only potash deficiency symptoms were evident in flax at Centres A and E other nutrient levels are very low at the various centres. This is especially so with magnesium and potash at Centre A; manganese at Centres A, B and C; boron at Centres C, D and E, and phosphate at Centre F.

Conclusions.

The results suggest that good crops of flax can be grown under conditions of low nutrient status as regards nitrogen, phosphorus, potassium, calcium, magnesium, manganese, and boron. Flax as a field crop cannot be regarded as highly susceptible to any of these nutrient deficiencies. Although yields were not affected by manurial treatment (except phosphate treatment in F) the low nutrient conditions for various elements are reflected in the chemical data. It is evident (Table X) that while most crops fail due to a shortage of nutrients at these centres, flax appears to be unaffected although the mineral

element condition in the tissues is low. Some potassium deficiency symptoms were observed in Centres A and E, and it seems that when this constituent is below 0·70% K_2O visual symptoms may appear.

Summary.

(1) Centres where susceptible crops showed acute manurial deficiencies were chosen for flax nutrient trials.

(2) The experimental layout, notation and treatment for Centres A, B, C, D, E and F are listed.

(3) The soil data and visual symptoms in previous crops, for each centre, are indicated.

(4) The chemical analyses of mature flax straw are presented in Tables III–X, and include the major elements, calcium, magnesium, potassium, phosphate and trace elements iron, manganese and boron. A note is incorporated on methods used for the latter group of elements.

(5) Although the nutrient status can be very low in flax material from the varied centres, no visual symptoms were recorded except those of potassium at two centres, A and E.

(6) It is evident that flax has a low manurial requirement and thrives when most crops suffer from acute nutrient deficiencies.

Acknowledgments.

Many thanks are due to Professor T. Wallace for directing this work. His helpful advice and criticism have proved invaluable. Mr. J. O. Jones was responsible for provision of the samples for analysis from the field plots.

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INVESTIGATIONS ON COMPOSTING. STRAW-SLUDGE COMPOSTS. PROGRESS REPORT I.

By P. T. H. PICKFORD, J. O. JONES & J. C. TODD.

It has long been realised that organic matter is a very important constituent of any productive soil. The chief functions attributed to the organic matter in soils are: (1) its effect on the micro-organisms of the soil; (2) its effect on soil structure and water holding capacity; (3) its value as plant food in supplying mineral elements to the soil, and (4) its effect, when well decomposed, as a colloid, in absorbing mineral nutrients and holding them in an exchangeable form.

Of recent years, with the increased mechanisation of agriculture, the question of supplying arable land with adequate amounts of organic matter has caused some alarm. Previous to the introduction of tractors and cars a good supply of dung was available and the farmer was able within limits to maintain the organic matter content of his soil from this source. The market gardener got his supply of dung from the towns, but these supplies are now much reduced. The question of furnishing any soil under continuous arable culture with a plentiful supply of organic manure has become a serious problem. To

make up for this lack of organic manures attention has been drawn to the benefits of composting crop residues. This is very useful when dealing with small areas of land, but presents considerable difficulties to the large scale market gardener and fruit grower. If composting is recognised as a general practice some basal material which can be obtained fairly cheaply and in quantity must be utilised. Straw is a possible material to fulfil these requirements at the present time when farmers must grow very large acreages of corn and find it difficult to utilise all the straw.

A number of experimental straw-sludge compost heaps were made during the summer months of 1944, using partially drained sludge fresh from the drying beds. The experiments were carried out in conjunction with the D.C.R.E. staff of the United States General Hospital at Tyntesfield, Somerset.

Method of Building the Heaps.

Seven heaps were completed, each of uniform size (10 ft. x 10 ft.) and containing approximately 1 ton of straw and 1½ tons (dry matter) sludge.

The method of building the heaps was similar throughout for the first six heaps, but the thicknesses of the layers of straw and sludge were varied. All the heaps with the exception of Heap No. 6 were aerated by means of varying numbers of six-inch land drain pipes at the base. Heap No. 6 was built on a foundation of bales of straw. Each heap received as much water as it would hold in the process of building. In all cases this was over 800 gallons. Additional water was added to the completed heap once a week during dry, hot weather. The sludge which had been allowed to drain for approximately a fortnight in the drying beds was lagooned on to the wetted straw, spread as evenly as possible and watered in. Alternate layers of straw and sludge were added until the heap was approximately 5 feet high.

The building of the heaps was done by the workmen in the course of their ordinary routine work, and the time spent on building each heap varied from 7 to 14 days according to available labour. In building the first heap it was decided to make this of six layers each of straw and sludge, staritng with a good layer of straw. The first layer of sludge was lagooned on to the straw without much difficulty, but it could not be washed in without running over the side of the heap. The second layer of sludge could not be held and the amount had to be reduced. As a result the amounts of both sludge and straw were reduced to a half after the first layer in building the first three heaps.

In the fourth heap the amount of each layer after the first was reduced to a quarter, thus making a heap containing 21 layers of sludge.

In heaps 5 and 6 all the layers were reduced to a quarter of the original amount, thus giving heaps with 23 layers of sludge. These thinner layers facilitated the building of the heap and the water was held much more readily.

The seventh heap was built up by using sludge which was already mixed with a small amount of straw lining the drying beds. The bottoms of the drying beds were covered with straw to a depth of 9 inches before the sludge was run in. After allowing a fortnight in the drying beds the sludge and straw were taken to build the heap. The heap was built up in the same way as the other heaps, with 17 layers of sludge, but using proportionally less fresh straw.

A single row of bales of straw placed round the outside of the base of the heap was helpful in keeping the heaps straight. In two cases these bales were left in this position for a few weeks after the heaps were completed. No apparent effect on temperature was recorded either during the time the bales were round the heap or when they were removed.

Full particulars of aeration and temperatures obtained at the two positions in the heaps are given in Table I.

Temperatures within the Heaps.

Weekly records were kept of the temperatures of each heap. These were taken in two positions; the centre of the heap and at three feet from the outside.

The maximum temperatures of all the heaps, which varied very little, was reached between the first and second week after making. The highest temperature recorded in any of the heaps within a fortnight after making was 125° F. in the centre and 135° F. at a position three feet inside the heap.

The fall in temperature was at a somewhat similar rate throughout, being between 10 and 20 degrees in two months. In all heaps except No. 6 the temperature in the centre was almost invariably 5° lower than the temperature taken 3 feet from the outside where aeration was evidently better. Heap No. 6 was built on bales of straw instead of drain pipes. The bales were placed in rows allowing 6 inches space between the bales. Here the temperature at the centre of the heap at the end of the first week was 125° F., while at 3 feet inside it was 135 F°. Four weeks later, however, a temperature of 112° F. was recorded at both positions, and up to 6 months after making the temperatures in the two positions were the same. From this it is evident that the use of bales in this manner resulted in a more uniform aeration than building on drain pipes.

Heap No. 7, in which the sludge used was mixed with a small proportion of straw in the drying beds, was 5 degrees lower in temperature at the centre than at the point 3 feet from outside for the first 6 weeks. Later, however, the temperatures at the two positions were similar. This more even temperature may have been due to the fact that the mixture of a little straw with the sludge as it was brought from the drying beds, made the sludge less compact and resulted in better aeration in the centre.

Examination and Analysis.

Six months after making, each of the heaps No. 1 to 6 was examined before being removed to Long Ashton. Heap No. 7, being only 3 months old at the time of writing, has not yet been opened up.

In each case the straw throughout the whole of the heap was found to have rotted satisfactorily with the exception of a very thin layer around the outside. Distinct layers of sludge and straw were still apparent, especially where the heaps had been built up in thick layers. However, where the heaps had been built up of thinner layers, the sludge and straw were much better intermixed.

On removing the heaps to Long Ashton they were restacked on the ground and the heaps placed close together to form one long, continuous heap. The heaps which were originally 10 x 10 x 5 feet now occupied a space of approximately $7\frac{1}{2}$ x 10 x $4\frac{1}{2}$ feet. Within a week after removal and rebuilding of the heaps the temperature rose again to the level reached soon after making. Two months after this turning the temperature of the first heap fell again to the same temperature as that recorded immediately before it was removed. From this it appears that the turning of the heaps some months after making may be beneficial in that it brings about further heating and decomposition.

Sampling for chemical analysis was done when the heaps were removed 6 months after making. It was done by taking rather large portions from different parts of the heaps and after mixing the portions together good repre-

TABLE I.

PARTICULARS OF SLUDGE–STRAW COMPOST HEAPS AT TYNTESFIELD.

Heap No.	Made	Base Aeration	No. of Layers of sludge	Temperature of Heaps in Degrees F.							
				Maximum during first 2 weeks		3 months after making		6 months after making		Maximum after turning at 6 months	
				Centre	Side	Centre	Side	Centre	Side	Centre	Side
1	May 18th—25th	Pipes 3 rows	10	115	125	100	103	80	84	105	110
2	„ 30th—June 6th	Pipes 5 rows	11	120	130	95	100	69	70	110	110
3	June 7th—15th	Pipes 5 rows	10	115	135	95	100	78	80	125	135
4	„ 19th—30th	Pipes 2 rows	21	120	135	94	95	70	73	120	125
5	July 3rd—11th	Pipes 4 rows	23	120	125	85	87	70	75	125	120
6	„ 27th—Aug. 10th	Bales 3 rows	23	125	130	100	100	80	80	120	120
7	Oct. 3rd—16th	Pipes 3 rows	17 (sludge with straw from drying beds)	120	125	100	105	—	—	—	—

sentative samples were packed in air-tight tins. The chemical data on all the samples are presented in Table II.

TABLE II.

PERCENTAGE COMPOSITION AND YIELD OF STRAW/SLUDGE COMPOSTS.

	1	2	3	4	5	6	Average	Average for farm-yard manure
Moisture	70·8	75·0	72·8	72·6	78·9	73·5	73·9	—
Dry Matter ..	29·2	25·0	27·2	27·4	21·1	26·5	26·1	20
Organic Matter in D.M.	78·9	81·4	73·6	80·1	82·5	82·6	79·8	64
Ash in D.M. ..	21·1	18·6	26·4	19·9	17·5	17·4	20·2	36
Nitrogen in F.W. ..	0·82	0·59	0·62	0·73	0·52	0·78	0·68	0·6
Nitrogen in D.M. ..	2·99	2·36	2·29	2·65	2·44	3·00	2·62	2·2
Nitrogen in O.M. ..	3·79	2·90	3·11	3·31	2·96	3·63	3·28	3·5
Phosphate in D.M.	1·26	1·02	0·91	1·11	0·91	1·20	1·07	1·6
Phosphate in O.M.	1·60	1·25	1·24	1·39	1·10	1·45	1·34	—
Potash in D.M. ..	0·20	0·28	0·26	0·31	0·21	0·24	0·25	1·0
Potash in O.M. ..	0·25	0·34	0·35	0·39	0·25	0·29	0·31	—
Yield in cwt. ..	77	103	86	112	111	139	104·7	—

Note: D.M. = Dry Matter. O.M. = Organic Matter. F.W. = Fresh Weight.

The data in Table II do not suggest that slight variations in the method of building up the heaps had any effect on the yield or composition of the resulting compost.

The nitrogen content is about equal to that of a fairly well rotted yard manure, phosphate is slightly lower and potash is very much lower.

Conclusions.

Satisfactory rotting of straw takes place in straw/sludge compost heaps with about one and a-half parts of sludge dry matter to one part of straw, provided the heap is satisfactorily wetted and aerated.

An average yield of $5\frac{1}{4}$ tons of compost was obtained at the end of six months from one ton of straw and $1\frac{1}{2}$ tons of sludge dry matter.

A more even temperature was obtained when aeration was most satisfactory. This was the case when the heap was built on straw bales.

The nitrogen and phosphate content of straw-sludge compost is comparable to an average sample of farmyard manure.

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EXPERIMENTS ON THE CONTROL OF WEEDS IN ONIONS.

By R. L. WAIN.

The efficient suppression of weeds in onion beds is essential for the production of a good crop especially in the early stages of growth when weed competition may prevent the onions from becoming established. Spraying with sulphuric acid (*e.g.* Hickman and Bennett, 1941 ; Blackman, 1943a, 1943b ; Ministry of Agriculture Advisory Leaflet No. 309) has given excellent weed control and enables hand labour to be cut down to a minimum. Unfortunately the use of this material has several disadvantages—the operator is compelled to wear protective clothing, there is risk of accident in diluting and handling the concentrated acid, and the spray machinery must be specially manufactured to withstand corrosion (Kearns, 1942). A satisfactory substitute for sulphuric acid as far as possible free from these disadvantages, is therefore highly desirable.

The severe damage caused to undercrops by dinitro-*ortho*-cresol (D.N.C.)-petroleum washes has led to the examination of such compounded products as weed killers (*e.g.* Robinson, 1944). The phytotoxic action of these washes is largely due to their D.N.C. content. Since the present work began, Blackman (1944) has discussed the use of sprays containing ammonium dinitro-*ortho*-cresylate or sodium dinitro-*ortho*-cresylate with ammonium sulphate for the control of annual weeds in cereals.

In this report, the efficacy of various solutions containing D.N.C. for controlling weeds in onions was compared with that of the standard sulphuric acid treatment.

Preliminary Trial in 1943.

In this " sorting out " experiment for which 47 11-ft. rows of onions were available, post-emergence sprays containing 1% D.N.C. as sodium salt, 0·5% D.N.C. as sodium salt both alone and with ammonium chloride, 0·5% D.N.C. as ammonium salt, 1% picric acid as ammonium salt, and 0·5% 2:4-dinitrophenol as ammonium salt, were compared with a sulphuric acid treatment consisting of 10% B.O.V. (Brown Oil of Vitriol).

The onions were divided into 3 blocks with two rows in each block per treatment, and the spray was applied on May 27th, using a hand pneumatic sprayer at the rate of $\frac{1}{3}$ pint per row. The onions were some 3-4″ high and there was a severe weed infestation in the rows though the ground between the rows had been kept clean.

All the sprays containing D.N.C. were found to be effective weed killers, but it was clear that, at equivalent concentrations, the ammonium salt, and the sodium salt with ammonium chloride were superior to the sodium salt alone. The sprays containing 1% D.N.C. as sodium salt and 0·5% dinitrophenol as ammonium salt were effective weed killers, but caused some damage to the onions, whilst the ammonium picrate treatment was almost completely ineffective.

The general conclusion from this preliminary trial was that the effects of ammonium dinitro-cresylate and the sodium salt with ammonium chloride, applied at a concentration equivalent to 0·5% D.N.C. were promising and warranted further investigation.

1944 Trial.

Materials and Methods.

The treatments were as follows :—

S1	Sulphuric acid pre-emergence spray only (13½% B.O.V.).
S2	,, ,, pre-(13½%) and post-(10%) emergence sprays.
S3	,, ,, post-emergence spray only (10% B.O.V.).
A	0·45% D.N.C. as ammonium salt. Pre- and post-emergence.
B	0·17% D.N.C. as sodium salt + ammonium chloride pre- and post-emergence.
C	0·34% D.N.C. ,, ,, ,, + ,, ,, ,, ,, ,, ,,
D1	0·51% D.N.C. ,, ,, ,, + ,, ,, pre-emergence only.
D2	0·51% D.N.C. ,, ,, ,, + ,, ,, pre- and post-emergence.
D3	0·51% D.N.C. ,, ,, ,, + ,, ,, post-emergence only.
H	Hand-weeded.
U	Untreated except for inter-row cultivation.

Approximately ⅓ of an acre was sown on March 28th with the variety Bedfordshire Champion in rows 1 ft. apart. The area was then divided into 2 blocks and each block was marked out into 12 plots 24 x 25½ ft. (*i.e.* 68 sq. yds.), giving 1 plot in each block per treatment, except the hand-weeded plots, two of which occurred in each block.

The spray for treatment A was made by dissolving 8 ozs. ground D.N.C. (91·8% by analysis) in 10 gallons of water containing 2¾ fl. ozs. ammonium hydroxide (d. 0·88).

That for the D treatments was obtained by dissolving 13·33 ozs. sodium dinitro-cresylate (63% sodium salt by analysis) + 3·5 ozs. ammonium chloride in 10 gallons of water, and this, appropriately diluted, gave the spray solutions for treatments B and C.

Spraying.

The solutions were applied using a small acid spray outfit (Kearns, 1942) at a rate as near as possible to 150 gallons per acre.

(*a*) *Pre-emergence applications.* The object of the pre-emergence spraying was to destroy all weeds present before the onion seedlings appeared. The applications were made on April 13th. There were seedlings of dicotyledonous weeds fairly evenly distributed over the whole experimental area. A heavy shower at 9 a.m. had left the surface soil still moist when spraying was commenced. The weather was warm and the sun shone intermittently.

(*b*) *Post-emergence applications.* The success of post-emergence spraying depends on the fact that whereas most weeds are easily wetted, onion foliage is not and therefore escapes damage. Applications were made on May 22nd. The plots which had received pre-emergence D.N.C. sprays were very bare, though weeds were becoming established on those which received the pre-emergence acid treatment. There was a heavy weed infestation in the unsprayed plots. The onions on the untreated and acid-sprayed plots were 3-4″ high and growing well. The ground was very dry and the weather ideal for spraying.

Climatic Conditions.

Apart from a very dry period extending, except for some rainfall on May 15th from April 19th to June 26th, during which the ground tended to become caked and cracked, abnormal weather was not experienced.

Manuring.

1 cwt./acre of nitrate of potash was applied to all plots on May 2nd.

Cultural Operations.

Inter-row cultivation using a Planet-push hoe was performed in all plots on April 27th and May 9th; the inter-rows were Dutch hoed on May 15th, 25th and July 6th. The 4 H plots were hand-weeded (hand hoes) on May 23rd, June 6th and August 9th.

The onion tops were bent over on August 17th, the crop lifted on Sept. 15th, turned on Sept. 18th, bagged and weighed on Sept. 24th.

Results.

(*a*) *Effect of pre-emergence sprays.*

Sulphuric acid (*S*1 *S*2).

Weed. The spray gave a rapid and almost complete control of all the dicotyledonous weeds. There appeared to be no "residual" weed killing effect, for a new crop of weeds soon appeared after rainfall on May 15th.

Onions. Emergence was good and by comparison with that in the untreated plots was unaffected by the spray. No scorching of the tips of the onions was observed.

D.N.C. (*A, B, C, D*1 *and D*2).

Weed. In all these plots weeds were completely killed, appearing within 2-4 days as shrivelled yellow seedlings lying flat on the soil surface. In spite of the differences in concentration there was little difference in the effect of these treatments except that the B treatment was slightly inferior.

A striking effect was the marked persistent weed killing action of the pre-emergence D.N.C. sprays. Thus, after 5½ weeks, on May 22nd, when the post-emergence application was made, the A, C, D1 and D2 plots were almost completely bare and there was only 5-10% weed infestation on the B plots, whereas a new crop of weeds was flourishing uniformly on the plots which had received the pre-emergence sulphuric acid spray. The residual effect of the D1 treatment certainly persisted well into June, there being less than 5% weed on June 24th. Even on August 14th, the weeds, though well developed, were not numerous and there was still an appreciable amount of bare ground.

Onions. Emergence was extremely poor, especially in the C, D1 and D2 plots, and most of the few seedlings which did appear were scorched at the tips. Thus on May 12th it was recorded that "the plots had a very bare appearance almost completely free of weeds and onions," whereas the complete rows of onions on the acid sprayed plots were 2-3″ high and just passing out of the "crooked" stage.

Worms. It might be interesting to record that the day after the pre-emergence spray was applied, a number (3 14) of dead worms were observed on the surface of all plots which had received the sprays containing D.N.C. A similar effect on worms is commonly seen in the fruit plantation after spraying with D.N.C.-petroleum washes.

(*b*) *Effect of post-emergence sprays.*

Sulphuric acid (*S*2 *and S*3).

Weed. The effect on the S3 plots was not completely satisfactory, for much of the weed, in spite of bad scorching, apparently recovered. Thus after 2 weeks, on June 6th, these plots carried 25—30% weed consisting mainly of big plants. Weeds on the S2 plots were smaller in size at the time of spraying than those on the S3 plots, and consequently a much better kill was obtained, only 1—8% infestation being recorded on June 6th.

Onions. Some scorch of onions occurred amounting to fairly marked damage in the S3 plots. The plants apparently recovered, however, and suffered little set-back.

D.N.C. (*A*, *B*, *C*, *D*2 and *D*3).

Weed. The A, C, and D2 plots were practically free of weeds before spraying. On these as well as the B plots all existing weeds were killed by the post-emergence spray. On the D3 plots the fair crop of rather large weeds was controlled more satisfactorily than was the case on the S3 plots. However, some of the larger weeds were not killed by the spray, and on June 6th a 10—20% weed infestation was recorded.

Onions. Slight damage was caused to onions in the D3 plots but the plants appeared to recover rapidly.

Worms. No dead worms were found the day after spraying.

(*c*) *Hand-weeded plots.*

Onion emergence was fairly uniform throughout the 4 H plots, but rather more vigorous growth was noted in one plot throughout the season. This difference was reflected in the final yields (Table I).

The 3 hand weedings gave plots similar in appearance (August 14th) to the S2 plots.

(*d*) *Untreated plots.*

Onion emergence was good in both of the U plots, but the ground rapidly became choked with weeds and it soon became difficult to see the onion plants, particularly in one of the plots, which for some reason carried a heavier weed infestation from the start. On May 23rd nine different species of weed were present in amounts above 1%. The 80—90% infestation was made up of Chickweed (40—60%), Speedwell (10—40%), Groundsel (5—15%), as well as Fumitory, Fat Hen, Mayweed, Dock, Potato, Couch Grass, and Sow Thistle.

Yields.

The total yield of onions from each plot is given in Table I, together with the average yield per acre for each treatment.

Discussion.

This trial reveals in a most striking manner the danger of using pre-emergence sprays containing D.N.C. On the D1 and D2 plots which received the highest concentration (0·51%) of D.N.C., only very few onions emerged. It is perhaps of interest here to note that fair germination was obtained in part of a single row of one of the D1 plots—possibly due to slightly deeper sowing. Even these plants, however, were scorched at the tips. The lower concentrations of D.N.C. applied pre-emergence (A, B and C) had only a slightly less drastic effect upon onion emergence and a clear warning against the use of pre-emergence D.N.C. sprays on onion beds must therefore be made, though the persistent action of these sprays against weed germination emphasises their potential value as general weed killers.

Pre-emergence spraying with sulphuric acid (13½% B.O.V.) gave very satisfactory results, a good control of weeds with no damage to the onions. The quantity of post-emergence acid spray used (S3) could perhaps have been increased with advantage, for some of the weeds, in spite of severe damage, recovered. The D3 treatment gave at least as good weed control and judged on a yield basis there was little difference between these two post-emergence treatments (S3 and D3).

Owing to the small amount of weed on the A, B, C and D2 plots when the post-emergence applications were made, these sprays need hardly have

TABLE I.

Treatment	Applications	Plot 1	Plot 2	Average	Average yield per acre		Estimated cost per acre (approximate)		
							Inter-row cultivation	Treatment	Total
		lbs.	lbs.	lbs.	tons	cwts.	£	£	£
S1 (Sulphuric acid)	Pre-emergence	276¾	239¼	258	8	4	22	4	26
S2 (,, ,,)	Pre- and post-emergence	384¾	301¼	343	10	18	22	8	30
S3 (,, ,,)	Post-emergence	222¾	242¾	232¾	7	8	22	4	26
A (0·45% D.N.C. as ammonium salt)	Pre- and post-emergence	61¾	85½	73½	2	6¾	—	—	—
B (0·17% D.N.C. as sodium salt with ammonium chloride)	,, ,, ,, ,,	123¼	134¾	129	4	2	—	—	—
C (0·34% do.)	,, ,, ,, ,,	64½	49	56¾	1	16	—	—	—
D1 (0·51% do.)	Pre-emergence	48	5	26½	—	17	—	—	—
D2 (do.)	Pre- and post-emergence	1	3¼	2	—	1¼	—	—	—
D3 (do.)	Post-emergence	208	272	240	7	12½	22	9	31
H (Hand-weeded)	—	264½	313	321¼	10	4½	22	24	46
		434¾	272						
U (Untreated)	—	27½	1	14¼	—	9	—	—	—

been applied. In all cases, however, the weed present was satisfactorily controlled with little damage to the onions.

The state of growth of onions on similar plots particularly the hand-weeded, indicated that the fertility status across the experimental area showed slight variation. For this reason, no significant differences can be drawn between the yields from the S1, S2, S3, D3, and H plots. The average results, however, give an indication that the pre- and post-emergence spraying with sulphuric acid (S2) was the best chemical treatment employed in this trial, yielding a similar average weight of crop to that obtained from the hand-weeded plots.

Economic Aspects.

Apart from the obvious saving in labour, it is clear that spraying can be considerably more economical than hand-weeding. Costings made at this Station show that acid spraying using a wheeled manual outfit can be performed at say £4 per acre. That of D.N.C. spraying (0·51%) works out at say £4 10s. 0d. per acre, but the fact that here there would be less risk of corrosion of the machine and no need for expensive acid resistant clothing has not been taken into account. These costings must be compared with that of approximately £8 per acre for each hand-weeding.

The costs per acre of each successful treatment, together with those for the inter-row cultivation at say £2 per acre and dutch hoeing the inter-rows at say £6 per acre, both of which were performed uniformly throughout the experimental area, are given in Table I. These figures, although necessarily approximate, when taken with the respective yields, do at least indicate the decided economical advantage of a pre-and post-emergence spraying with sulphuric acid over hand-weeding.

These experiments will be continued during the 1945 season.

Summary.

1. Spraying with sulphuric acid and with various solutions containing dinitro-*ortho*-cresol for controlling weeds in onions was compared with a normal hand-weeding programme.

2. Pre-emergence spraying with the D.N.C. preparations produced disastrous results, most of the onions failing to emerge. These sprays, however, had a considerable " residual " effect in preventing the germination and growth of weeds.

3. Post-emergence spraying with 10% sulphuric acid and with a solution containing 0·51% D.N.C. gave similar weed control and similar yields were recorded.

4. Pre- and post-emergence spraying with sulphuric acid gave an excellent yield of onions similar to that obtained from the hand-weeded plots. The cost of the spraying treatment, however, was decidedly lower than that of hand-weeding.

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THE QUALITATIVE EXAMINATION OF INSECTICIDAL PROPERTIES. PROGRESS REPORT, 1944.

By H. MARTIN & R. L. WAIN.

It is convenient to discuss the 1944 work on this subject under two headings; firstly, that on methods and their adaptability to quantitative work; secondly, the application of the methods to the study of insecticidal action particularly of polychlorethanes and related compounds.

METHODS.

Stomach Poisons and Repellents.

The sandwich method (Martin, Stringer and Wain, 1944), in which the chance of contact action is reduced by placing the insecticide between two leaf discs, enables an assessment of the amount of poison ingested by the insect. It might therefore serve as a quantitative method, a possibility which was examined by observations on individual larvae of known weight fed with sandwiches containing different amounts of insecticide.

Larvae of the Cabbage Moth (*Mamestra brassicae* L.), hand-picked from brussel sprout plants, were weighed on a spring balance and fed with sandwiches each containing either 1 mg. or 0·2 mg. D.D.T. ($\alpha\alpha$ bis (4-chlorphenyl)-$\beta\beta\beta$ trichlorethane, m.p. 107° C). The amount of sandwich eaten before the larvae succumbed was estimated by eye and the lethal dose adjusted by direct proportion to a body-weight of 0·3 g. With sandwiches containing 1 mg. the mean lethal dose was 0·62 mg.; with those containing 0·2 mg. it was 0·074 mg. D.D.T.

The simplest explanation of this divergence is that the larva is able, because of the slow speed of action of the insecticide, to consume more than the toxic dose before it becomes affected and ceases to feed. To test this explanation, the toxicity of the newly-poisoned larvae to other larvae was examined either by offering the dead larva as food or by feeding with an ether extract of the dead larva after desiccation at ordinary temperatures in vacuo.

In the former experiments, the possible toxicity of non-poisoned larva was controlled by offering, as bait, larvae previously fed on lanolin-treated leaf discs and killed by pressure on the first thoracic segment, care being taken to avoid rupture of the cuticle. Controls were also included to cover the possibility that D.D.T. leaves within the dead larvae a poisonous decomposition product, the method being to include larvae fed, before killing, on the related non-toxic polychlorethylene D.D.X. ($\alpha\alpha$ bis (4-chlorphenyl)-$\beta\beta$ dichlorethylene). The results of these tests, assembled in Table I, show that the D.D.T.-killed larvae retain greater insecticidal properties than those killed after feeding on D.D.X.; the larvae killed by crushing are non-toxic.

For the tests of the ether extract of dried larvae, the latter were fed before death with lanolin-treated sandwiches with or without D.D.T. Acetone solutions of the ether extract were used to prepare sandwiches fed to fresh larvae. In Exp. P18, four of the six *M. brassicae* fed with the extract of D.D.T.-poisoned larvae showed typical symptoms of poisoning after 90 hr. consuming an average of 1·6 discs (= 0·0112 mg. D.D.T. calculated on the amount taken by the extracted larvae); all six, each fed with five sandwiches containing the extract of unpoisoned larvae, and the five fed with lanolin-treated sandwiches were normal after 90 hr.

TABLE I.

INSECTICIDAL PROPERTIES OF BAIT LARVAE.

Exp. No.	Test larva	Bait larva			Effect on Test larva	
	wt. g.	wt. g.	Cause of death	Bait taken	After 48 hours	After 96 hours
P9	0·29	0·14	0·05 mg. D.D.T.	All	Moribund	Unable to eat fresh food
	0·30	0·14	0·05 mg. D.D.T.	All	Affected	Able to eat fresh food
	0·40	0·56	0·13 mg. D.D.T.	Partially	Affected	—
	0·30	—	Crushed	All	Normal	Normal
	0·63	—	Crushed	All	Normal	Normal
P14	0·47	0·38	0·05 mg. D.D.T.	Nearly all	Affected	Survived
	0·45	0·28	0·12 mg. D.D.T.	Nearly all	Affected	Survived
	0·35	0·32	0·10 mg. D.D.T.	Nearly all	Affected	Dead
	0·46	0·53	0·10 mg. D.D.T.	Nearly all	Affected	Survived
	0·36	0·24	0·10 mg. D.D.T.	Nearly all	Affected	Dead
	0·38	0·60	0·10 mg. D.D.T.	All	Dead	—
	0·33	0·25	Crushed (1·0 mg. D.D.X.)	All	Normal	Normal
	0·38	0·46	Crushed (1·0 mg. D.D.X.)	All	Normal	Normal
	0·43	0·64	Crushed (1·0 mg. D.D.X.)	All	Affected	Survived
	0·47	0·12	Crushed (0·75 mg. D.D.X.)	All	Dead	—
	0·49	0·20	Crushed (1·0 mg. D.D.X.)	All	Normal	Normal
	0·55	0·32	Crushed (1·0 mg. D.D.X.)	All	Normal	Normal
	0·54	0·28	Crushed	All	Normal	Normal
	0·40	0·57	Crushed	All	Normal	Normal
	0·45	0·38	Crushed	All	Normal	Normal
	0·43	0·37	Crushed	All	Normal	Normal
	0·60	0·32	Crushed	All	Normal	Normal
	0·55	0·58	Crushed	Half	Normal	Normal

These results support the conclusion that the sandwich method will give an exaggerated estimate of the lethal dose, the extent to which it exceeds the true lethal dose being dependent on the speed of action of the toxicant and the appetite of the individual larva. If therefore the method is to be developed on quantitative lines, safeguards are necessary to control the influence of these two factors on mortality-dosage relationships.

Contact Insecticides.

In addition to the method, described in the 1943 Report, in which the test organisms are dusted, a test was developed in which the organism was placed in contact with a treated surface. A known amount of the toxicant, dissolved in a volatile solvent such as acetone or chloroform, was pipetted on to a 9 cm. filter paper (Whatman No. 50) and the solvent allowed to evaporate. The treated paper was then placed in a suitable petri-dish, the organisms placed on the paper and their behaviour observed. Plugs of cut potato tuber were added if the organisms, *e.g.* woodlice, were susceptible to low humidities and, with leaf-eating larvae, appropriate food material was added. Moribund or dead organisms were removed to avoid cannibalism and the consequent possibility of stomach poison action.

Because the toxicant is applied, not directly to the organism, but to a surface prior to its invasion by the pest, this method of application may be described as protective on the analogy of the protective fungicide applied to the leaf surface before the plant is attacked by the fungus spore. The use of the principle in plant pest control has previously been limited because the available insecticides were either readily decomposed on exposure to sunlight to non-insecticidal substances, *e.g.* the pyrethrins and rotenone, or were rapidly lost from the sprayed surface by volatilization, *e.g.* nicotine. Potter (1938) first discovered that a deposit of pyrethrins in a non-volatile oil on the walls and contents of warehouses killed the migratory larvae of certain pests of dried fruit. More recently Tattersfield and Potter (1943) and Parkin and Green (1943) have examined this method of application for the quantitative bio-assay of pyrethrum insecticides and, because the insecticide is presented to the insect in a film of non-volatile solvent, the method has been named the film technique.

The present method differs in that the film is solid, *i.e.* the filter paper impregnated with the toxicant in crystalline form, but it might be amenable to development for quantitative work. The response of woodlice to increasing dosages of toxicant is shown in Table II ; in the one case the woodlice were allowed to wander on dry filter papers impregnated with D.D.T. and, in the other case, when the impregnated filter papers were subsequently oiled with a high-boiling refined petroleum oil (P31) of the grade used in glasshouse sprays. It is evident that the presence of the oil has not affected the toxicity of the D.D.T. deposit. Combining all figures for statistical analysis and assuming that the index of variation is zero (though the incomplete kill at higher concentrations suggests that it is negative), the relationship between toxicity and concentration is :

$$Y = 4{\cdot}050 + 1{\cdot}282\ X$$

where Y is probit mortality and X is the log. concentration of D.D.T. expressed as mg. per filter paper. Although the difference between the results expected from this equation and those observed, when expressed by Chi^2 is 78·230 ($n = 10$), is large and indicates disturbing factors other than those of random sampling, the method is well able to detect major differences in toxicity.

TABLE II.

Relationship between Dosage and Effect in Protective Contact Toxicity Tests.

Exp. W8 : *Armadillidium* sp. ; 42 hours exposure		Exp. W10 : *Armadillidium* sp ; 46 hours exposure	
Deposit mg. per 63·6 cm.²	Effect	Deposit mg. per 63·6 cm.²	Effect
0·0 D.D.T.	11/12 ; 20/20 ; 20,21 normal	0·0 D.D.T. + 1 ml. P 31	11/12 ; 10/12 ; 12/12 normal
5·0 ,,	6/12 ; 9/12 normal	5·0 ,, + 1 ml. P 31	10/12 ; 5,12 normal
10·0 ,,	3/12 ; 2/12 normal	10·0 ,, + 1 ml. P 31	3/12 ; 2/12 normal
20·0 ,,	4/12 ; 1/12 normal	20·0 ,, + 1 ml. P 31	1/12 ; 0/12 normal
40·0 ,,	3/12 ; 2/12 normal	40·0 ,, + 1 ml. P 31	0/12 ; 0/12 normal
80·0 ,,	1/12 ; 0/12 normal	80·0 ,, + 1 ml. P 31	2/12 ; 1/12 normal

APPLICATIONS.

The methods have been applied to the critical survey of the toxic properties of compounds analogous to D.D.T. which had, in 1943, been found an outstanding contact and stomach insecticide. A compound or mixture isolated from a proprietary product " P.P. Flea Beetle Dust " and a series of simpler nitriles, a continuation of the preliminary work begun in 1943, have received a less intensive study.

A. Polychlorethane derivatives.

(*i*) *The compatibility of D.D.T.*

If D.D.T. is to be used in the field, satisfactory methods of compounding to forms suitable for spray or dust application are required. The accessory components used in compounding such as the surface-active components added to delay crystallization of D.D.T. in the spray tank, must be chosen from those which do not interfere with the insecticidal properties of D.D.T. Nor should fungicides or acaricides, added to extend the toxicity of the spray to fungi and to acarids, reduce the efficiency of D.D.T. either by chemical or physical incompatibility.

Chemical studies have shown D.D.T. to be surprisingly unreactive and the only apparent cause of chemical incompatibility is the tendency to eliminate hydrogen chloride to form the dichlorethylene derivative (D.D.X.) thus : —

$$(C_6H_4Cl)_2CH.Cl_3 \xrightarrow[KOH]{\text{alcoholic}} (C_6H_4Cl)_2C{=}CCl_2$$

As the dichlorethylene is non-insecticidal it is important to know whether this reaction will proceed at ordinary temperatures in the presence of mild alkalies such as hydrated lime. This point is easier to examine chemically. D.D.T. was accordingly deposited on the walls and base of large glass dishes which were then filled with an alkaline material such as milk of lime, Bordeaux mixture or lime sulphur. The dishes were exposed outdoors for several months and at intervals the contents were tested for soluble chlorides. In the D.D.T.-treated dishes and in those filled with the fungicides alone, all tests were negative, showing that the above reaction had not proceeded.

To determine whether any less obvious reaction occurred leading to a reduction in insecticidal potency, the effects on woodlice of films of D.D.T. and of D.D.T. subsequently treated with lime sulphur were compared. In the latter tests the filter paper, after evaporation of the acetone, was impregnated with dilute lime sulphur in the ratio of 0·5 ml. 20% lime sulphur per 10 mg. D.D.T. (*i.e.* assuming a spray strength of 1 gal. lime sulphur (sp. gr. 1·3) and 1 lb. D.D.T. per 100 gal.). After 65 hrs. on non-impregnated paper all the woodlice (*Armadillidium* sp.) were unaffected ; on paper impregnated with lime sulphur, all of 13 and 12/13 appeared unaffected in two tests ; on paper bearing 10 mg. D.D.T. per paper, 10/13 and 10/12 appeared unaffected, while on similar D.D.T. papers impregnated with lime sulphur, 8/15 and 6/12 appeared normal after 65 hrs. The potency of the D.D.T. had not been reduced by the lime sulphur treatment.

A type of physical incompatibility might arise if the supplementary component is able to absorb strongly or to include the insecticide. Campbell and West (1944) observed that, when applied in oil paints and synthetic varnishes, D.D.T. was less effective in rendering the painted surfaces toxic to flies than when applied in an oil-bound water-paint. As present evidence indicates that D.D.T. is ineffective against Red Spider, the inclusion of an acaricide such as petroleum oil of summer grade may be necessary. The

results given in Table II indicate that the addition of the oil will not reduce the effectiveness of D.D.T. against woodlice ; confirmatory evidence, included in Table III, was obtained by the use of D.D.T. at 10 mg. per filter paper, 0·5 ml. summer grade petroleum oil being added to the paper after the evaporation of the solvent.

Table III also contains results obtained with a sample of hexachlorcyclohexane ($C_6H_6Cl_6$) recovered from a proprietary flea beetle dust. The efficiency of this substance against woodlice is markedly reduced when the filter paper is oiled, an effect which may be associated with the low solubility of the insecticide in the oil and by an interference with volatilization, for $C_6H_6Cl_6$, unlike D.D.T., is capable of " action at a distance." When, for example, the impregnated filter paper was held within the lid of the petri dish in Exp. W2 (Table III), 11/25 woodlice remained apparently unaffected after 60 hrs., whilst when the paper was oiled and again held in the lid of the dish out of contact with the woodlice all sixteen remained unaffected after 54 hrs. (Exp. W4).

(*ii*) *The effects of p-substituents on the toxicity of D.D.T.*

From the few results of the 1943 trials on the analogues of D.D.T., it was concluded that insecticidal properties were to some degree specific to the *p*-chloro derivative. Neither the unsubstituted diphenyl-trichlorethane nor the *p*-hydroxy-derivative and its acetate were toxic.

During the past year analogues of D.D.T. with *p*-substituents other than chlorine have been synthesised and subjected to such tests as the limited amount of biological test material permitted. Particulars of the compounds and of the corresponding ethylenes, obtained by refluxing with alcoholic potash, are :—

aa bis (4-*fluorophenyl*)-*ββ trichlorethane* (Difluoro-D.T.) : from fluorobenzene and chloral. Bulk of product, b.p. 133–134° /1 mm. was a colourless oil, *n* 20° 1·5707. Recrystallized twice from methyl alcohol, m.p. 45°C. Found : C, 52·32 ; H, 2·77 ; $C_{14}H_8F_2Cl_3$ requires C, 52·26 ; H, 2·84 %.

aa bis (4-*fluorophenyl*)-*ββ dichlorethylene* (Difluoro-D.X.) : A colourless oil (*n* 20° 1·5838) which solidified on standing. White needles from methyl alcohol, m.p. 43°. Found : C, 58·78 ; H, 3·06 ; $C_{14}H_8F_2Cl_2$ requires C, 58·95 ; H, 2·83%.

aa bis (4-*bromophenyl*)-*βββ trichlorethane* (Dibrom-D.T.) : from bromobenzene and chloral, crystallizes from alcohol in needles m.p. 140°. Zeidler (*Ber. 7* 1180) gives m.p. 139–141°.

aa bis (4-*bromophenyl*)- *ββ dichlorethylene* (Dibrom-D.X.) : Shining white plates from alcohol, m.p. 119–120°. Zeidler (*loc. cit.*) gives m.p. 119–120°.

aa bis (4-*iodophenyl*)- *βββ trichlorethane* (Diiodo-D.T.) : from iodobenzene and chloral, crystallizing from alcohol in colourless compact prisms, m.p. 173°. Chattaway and Muir (*J.C.S.* 1934, 702) give m.p. 172°.

aa bis (4-*iodophenyl*)- *ββ dichlorethylene* (Diiodo-D.X.) : colourless plates from alcohol m.p. 141°. Found : C, 33·59 ; H, 1·83. $C_{14}H_8I_2Cl_2$ requires C, 33·55 ; H, 1·61%.

aa bis (4-*methoxyphenyl*)- *βββ trichlorethane* (Dimethoxy-D.T.) : from anisole and chloral, when recrystallized thrice from methyl alcohol gives large white prisms of m.p. 89°. Elbs (*J. pr. Chem.* (2) *47*, 68) gives m.p. 92° ; Fritsch and Feldmann (*Annalen, 306*, 77) gives m.p. 89° ; Frankforter and Harris (*J. Amer. Chem. Soc. 48*, 3144) gives m.p. 94°.

aa bis (4-*methoxyphenyl*)- *ββ dichlorethylene* (Dimethoxy-D.X.) : Stout needles m.p. 109–110° from alcohol. Fritsch and Feldmann (*loc. cit.*) gives m.p. 113° ; Frankfurter and Kritschevsky (*J. Amer. Chem. Soc. 36*, 1511) give m.p. 109°.

aa bis (4-*methylphenyl*)- *βββ trichlorethane* (Dimethyl-D.T.) : from toluene and chloral hydrate. Colourless plates from methyl alcohol, m.p. 89–90°. Fischer (*Ber. 7*, 1191) gives m.p. 89°. Found : C, 61·27 ; H, 4·91. $C_{16}H_{15}Cl_3$ requires C, 61·27 ; H, 4·82%.

aa bis (4-*methylphenyl*)- *ββ dichlorethylene* (Dimethyl-D.X.) : long needles from methyl alcohol, m.p. 87°. Fischer (*loc. cit.*) gives m.p. 92°. Found : C, 69·11 ; H, 5·17 ; $C_{16}H_{14}Cl_2$ requires C, 69·31 ; H, 5·09%.

aa diphenyl-ββ dichlorethylene : by warming an alcoholic solution of *aa* diphenyl-*βββ* trichlorethane (see 1943 Report) with an alcoholic solution of sodium ethoxide. Prisms from alcohol, m.p. 79–80°. Baeyer (*Ber. 6*, 223) gives m.p. 80°.

aa bis (4-*amidophenyl*)- *βββ trichlorethane* (Diamido-D.T.) : when 2 drops of 20% oleum were added to a well-stirred mixture of benzonitrile (2 mols.) and chloral (1 mol.) the whole set

TABLE III.

Effect of Oil on Toxicity of adsorbed Films to Woodlice.

Test No. and organism	Time. Hr.	D.D.T. Film		$C_6H_6Cl_6$ Film		Control	
		Not oiled	Oiled	Not oiled	Oiled	Not oiled	Oiled
W2 *Armadillidium* sp.	60	10/27	—	0/21	—	27/31	—
W4 *Armadillidium* sp.	54	—	4/18	—	13/14	—	16/16
W6 *Armadillidium* sp.	42	6/8 2/8*	6/9 2/12*	0/10	7/8	6/8	9/9
M39 Other spp.	70	22/32 21/27	0/31 0/26	0/40 0/45	48/56 30/45	20/20	19/23 20/23

* 50 mg. D.D.T. per filter paper.

to a glassy mass from which a substance (white needles, m.p. 272–273° (d)) was isolated in good yield. Found : C, 51·56 ; H, 3·52 ; N, 7·65 ; Cl, 28·77 ; mol. wt. (Rast) 353. $C_{16}H_{13}N_2Cl_3O_2$ requires C, 51·68 ; H, 3·53 ; N, 7·54 ; Cl. 28·64% ; mol. wt. 371·5. These figures therefore indicate the diamide. But attempts to hydrolyse this compound, both with 70% H_2SO_4 or 10% alcoholic potash failed, the molecule breaking down, with the liberation of chloral, to benzoic acid. As no other D.D.T. analogue examined gave chloral with these treatments, the formula of the substance may not be as given above and the material is being further investigated.

Bioassays.

For direct contact toxicity tests the powders were prepared from a mixture of gypsum (19 parts) and amorphous silica (1 part by wt.). The results, assembled in Table IV, are given as the number of apparently unaffected woodlice as a fraction of the number treated with a dust containing the stated percentage of polychlorethane. Of the corresponding ethylenes, D.D.X. was not tested, as the 1943 results showed it to be non-toxic in 5% dust. At this strength neither the dibrom-, diiodo-, dimethoxy-, nor the unsubstituted diphenyl-dichlorethylene caused a mortality in the woodlice or earwigs tested, greater than that in the controls.

For the protective contact toxicity tests, woodlice and a variety of insects were used with results assembled in Table V, the number apparently unaffected after the stated time again being expressed as a fraction of the number exposed on filter paper bearing the stated amount of polychlorethane. To save space, particulars of two experiments are sometimes given on the same line across the table, the results of the second test being included in parentheses. The ethylene derivatives were tested only on woodlice and even in deposits of 50·0 mg. per filter paper (Exp. M45), no evidence of toxicity was obtained except with difluoro-D.X., on which, only 18/42 and 15/33 survived 92 hr. With the same compound, at 10·0 mg. per paper, after 68 hrs., only 6/14 and 7/10 remained apparently unaffected, the figures of the control being 10/11 and 6/8 (Exp. P12).

The stomach poison tests were made with caterpillars collected from brussel sprouts. The results were as follows :—

Mamestra brassicae : none of eight survived a mean dose of 0·06 mg. dichlor-D.T. ; none of four survived a mean dose of 0·4 mg. dibrom-D.T. ; none of six survived a mean dose of 0·7 mg. diiodo-D.T. In the controls (Exps. P3, 5, 8, 24) all but one of the 31 larvae used survived, each consuming an average of 2·9 lanolin-treated sandwiches.

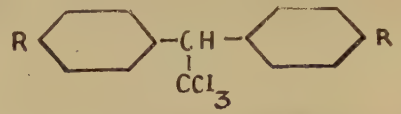
When fed with sandwiches containing the ethylene derivatives, however, all six receiving a mean dose of 1·2 mg. of dibrom-D.X., 5/6 receiving a mean dose of 4·8 mg. of diiodo-D.X. and all six taking an average of 1·1 mg. of the unsubstituted dichlorethylene survived after periods of 67-140 hrs. No repellent effect was observed, for similar amounts of leaf were eaten by the control larvae in these tests (Exps. P5, 24).

Pieris brassicae : Parasitism interfered in most tests but the three larvae, each receiving 0·006 mg. D.D.T. and the two receiving 0·008 mg. difluoro-D.T. did not survive 64 hrs., though 5/7 of those fed with an average of 3·8 untreated sandwiches remained normal (Exp. W12). Difluoro-D.X. proved toxic to six larvae, each fed with 0.2 mg., while all six control larvae receiving a total of 9·0 sandwiches survived 60 hrs. (Exp. P13).

P. rapae : In three trials only 2/16 larvae each fed with 0·1 mg. dibrom-D.T. survived 118 hrs., while 10/14 receiving an average of 1·2 mg. of dibrom-D.X. and 8/9 control larvae appeared to be unaffected (Exps. W33, 37, P6).

TABLE IV.

SYMMETRICAL ANALOGUES OF D.D.T. AS DIRECT CONTACT INSECTICIDES.



Test Organism and Number	Time hr.	Dichlor-D.T.(D.D.T.) R = Cl				Difluoro-D.T. R = F				Dibromo-D.T. R = Br	Diiodo-D.T. R = I	Dimethyoxy-D.T. R = OCH_3	Diamido-D.T. R = $CONH_2$	Control
		0·5	0·25	0·125	0·0625	0·5	0·25	0·125	0·0625	5·0	5·0	5·0	5·0	0·0% dust
Woodlice														
Armadillidium sp.														
W1	47	1/18 1/17	—	—	—	0/16 0/17	—	—	—	—	—	—	—	13/15 16/16
W3	58	—	9/18 5/19	—	—	—	0/16 0/16	—	—	—	—	—	—	13/15 15/15
W5	45	—	—	2/18 2/16	—	—	—	0/16 0/14	—	—	—	—	—	16/17 13/15
W9	70	—	—	—	3/14 1/14	—	—	—	3/16 0/15	—	—	—	—	14/14 14/14
		5·0		1·0		5·0		1·0		5·0	5·0	5·0	5·0	0
Other spp.														
M5	42	—		—		—		—		16/19 ; 10/22	—	15/17 ; 23/23	—	14/14 14/15
M6	47	—		—		—		—		1/19 ; 1/13	—	—	—	15/16
M2	46	—		5/27		—		0/21 0 0/23		—	—	10/19	—	11/12 21/25
V35	92	—		—		—		—		1/19 ; 9/22	—	—	—	12/14 13/15
P4	53	—		—		—		—		4/19 ; 1/13	—	—	—	15/19
P10	41	0/12 ; 0/11		—		0/20 ; 0/16		—		7/11 ; 7/10	16/16 ; 10/11	—	—	13/14 14/16
P17	71	—		—		—		—		—	—	—	— 19/23 ; 24/27	23/25 23/24

Discussion.

The halogen-substituted analogues of D.D.T. reveal a trend in insecticidal potency, which is greatest in the fluorine and least in the bromine and iodine analogues. This trend is well shown in direct contact action on woodlice (Table IV) and in protective contact action on *M. brassicae* and woodlice (Table V). Although the relative amounts taken in the stomach poison tests suggest a like trend, the method will not permit the interpretation of these amounts as minimum lethal doses.

The halogen-substituted analogues of D.D.X. show, on the other hand, a negligible toxicity in all tests except those of the difluoro-D.D., a property which may contribute to the toxicity of difluoro-D.T.

The effects of substitution of the *p*-chlorine atoms of D.D.T. by other organic radicals may be summarized thus :—

In the series $(4x\ C_6H_4)_2\ CH.CCl_3$:

when $x = H$	negligible toxicity	} see 1943 report.
$x = OH$	do.	
$x = O.COCH_3$	do.	
$x = CONH_2$	do.	
$x = OCH_3$	moderate toxicity.	
$x = CH_3$	do.	
$x = Cl$	high toxicity.	

It is evident that the nature of the nuclear substituent x affects toxicity, an effect which may be due to solubility factors or to the electronic effect of the group. When x is Cl or OCH_3 both electromeric and inductive effects are operative but are opposite in their influence on the α carbon of the ethane. The electromeric effect, if operative as far as this carbon atom, would tend to make it more negative than when x is H ; the inductive effect would tend to make it more positive. The general effect of the CH_3 group, on the other hand, would render this carbon atom more negative. As there is little difference in toxicity when x is OCH_3 or CH_3 no clear-cut reason for the influence of the substituent on toxicity emerges from a consideration of electronic effects which appear to be less important than the influence of solubility factors.

The Overton-Meyer theory relates, in broad terms, toxicity to the lipoid solubility of the toxicant and if, by the latter expression is meant the ability of the toxicant to penetrate to and to become absorbed at the site of action, the effects of the nuclear substituent on toxicity become apparent. The relatively non-polar -Cl, $-CH_3$ and $-OCH_3$ groups would make for greater lipoid solubility than the polar -OH, $-OCOCH_3$ and $-CONH_2$ groups. The former groups make for toxicity, the latter groups for non-toxicity in the D.D.T. analogues examined.

(*iii*) *The effects of asymmetry on the toxicity of D.D.T.*

It being known from the 1943 trials that the unsubstituted diphenyl trichlorethane is practically non-toxic, the intermediate phenyl-chlorphenyl analogue and the unsymmetrical *o-p*-dichlorphenyl derivative were examined.

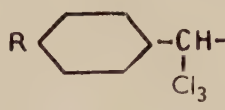
α *phenyl-α* (4-*chlorphenyl*)- *ββδ trichlorethane* : $C_6H_5CH(CCl_3).C_6H_4Cl$ by condensing *p*-chlorophenyl-trichloromethyl carbinol with benzene. Prisms from methyl alcohol, m.p. 74–75°. Chattaway and Muir (*loc. cit.*) give m.p. 74°.

α *phenyl-α* (4-*chlorophenyl*)-*ββ trichlorethylene* : by refluxing the above trichlorethane with alcoholic potash. Slender needles, m.p. 110° ; Chattaway and Muir (*loc. cit.*) give m.p. 93°. Found : C, 59·68 ; H, 3·11 ; $C_{14}H_9Cl_3$ requires C, 59·29 ; H, 3·20%.

α (2-*chlorophenyl*)-α (4-*chlorophenyl*)-*βδδ trichlorethane* (*o-p*-D.D.T.). The Geigy Colour Co. of Manchester kindly supplied a crude sample of this compound, m.p. 62–69°C. Recrystallized thrice from methyl alcohol, stout colourless needles m.p. 74–75°.

TABLE

SYMMETRICAL ANALOGUES OF D.D.T. AS



Test Organism and Number	Time hr.	Dichlor-D.T. (D.D.T.) R = Cl				Difluoro-D.T. R = F		Dibrom-D.T. R = Br		
		10·0	5·0	1·0	0·5	10·0	5·0	50·0	10·0	5·0
Woodlice										
Armadillidium sp. W23	66	14/17 12/14	—	—	—	—	—	—	—	—
W38 (P7)	47 (44)	—	—	—	—	0/12 0/17	— —	— —	12/12 9/9	— —
Other sp. M1	46	5/27	—	—	—	0/21 0/23	—	—	—	—
W34	48	—	—	8/18 3/8	10/12 9/10	— —	— —	— —	— —	— —
W38	47	—	—	—	—	0/18 0/17	— —	— —	15/15 18/18	— —
P15 (P16)	47 (71)	17/20 16/21	12/14 26/31	— —	— —	0/41 0/39	0/17 0/17	— —	26/28 24/27	34/46 8/25
M40	120	0/31 4/18	—	—	—	—	—	—	—	—
M41	114	0/28 0/16	—	—	—	—	—	—	—	—
		10·0	5·0	2·5	1·25	10·0	—	50·0	10·0	—
Soldier Beetles W26	20	0/7 1/6	— —	— —	— —	0/5 0/5	— —	— —	3/6 0/5	— —
W27	19	0/6 1/6	0/9 1/14	0/6 0/6	0/9 1/9	— —	— —	— —	— —	— —
M. brassicae P19 (P23)	93 (92)	0/6	0/6	—	—	—	—	(4/6)	—	—
P20	41	5/6	—	—	—	0/6	—	—	6/6	—
	89	1/6	—	—	—	0/6	—	—	6/6	—
		1·0	0·5	0·25	0.125	1·0	0·5	0·25	0·125	
Forficula sp. W36	69	0/3 0/4	0/4 0/4	0/5 0/4	3/4 4/4	0/4 0/4	0/6 0/6	0/4 0/5	1/3 0/4	— —

1.

OTECTIVE CONTACT INSECTICIDES.

Diiodo-D.T. R = I		Dimethyl-D.T. R = CH_3		Dimethoxy-D.T. R = OCH_3				Diamido-D.T. R = $CONH_2$	Control
10·0	5·0	50·0	10·0	50·0	10·0		1·0	10·0	0 mg. per 63·6 cm²
—	—	—	—	13/15 14/14	—		—	—	14/16 13/13
(13/13) (15/16)	— —	— —	— —	— —	12/12 11/11		— —	— —	7/7 (13/13) 11/11 (11/11)
—	—	—	—	10/19	—		—	—	11/12 21/15
— —	— —	— —	— —	— —	— —		18/18 11/11	— —	15/16 16/16
— —	— —	— —	— —	— —	21/21 12/12		— —	— —	18/19 15/15
21/27 17/19	10/11 27/27	— —	— —	— —	— —		— —	(20/23) (22/24)	20/20 (19/20) 17/17 (14/16)
—	—	3/32 9/40	— —	— —	— —		— —	— —	28/28 34/34
—	—	—	23/25 23/26	— —	— —		— —	— —	23/23 29/29
10·0	—	—	—	50·0	10·0	5·0	2·5	1·25	—	0·0 mg. per 63·6 cm²
— —	— —	— —	— —	— —	0/7 0/7	— —	— —	— —	—	7/7 6/6
— —	— —	— —	— —	— —	0/8 0/5	1/10 0/5	0/4 0/4	0/5 0/5	—	3/4 3/5
—	—	—	—	(6/6)	—	—	—	—	—	3/3 (6/6)
6/6	—	—	—	—	6/6	—	—	—	—	6/6
6/6	—	—	—	—	6/6	—	—	—	—	6/6
										0·0 mg. per 63·6 cm²
— —		— —		— —					— —	5/5 5/5

TABLE VI

ASYMMETRICAL D.D.T. ANALOGUES AS PROTECTIVE CONTACT INSECTICIDES.

Test Organism and number	Time hr.	*p-p*-D.D.T.		*o-p*-D.D.T.		4-chlorphenyl-phenyl trichlorethane		Control
		50·0	10·0	50·0	10·0	50·0	10·0	0 mg. per 63·6 cm.²
Woodlice								
P 31	116	—	—	—	—	—	15/15; 28/28	14/14
M 36	88	2/20; 10/22	—	15/29; 13/22	—	—	—	18/20; 24/24
M 37 (44)	136 (112)	0/28	(0/40; 6/42)	3/31	—	(27/47; 15/48)	—	27/27 (44/44; 33/33)
M 38	160	—	—	14/24; 16/33	15/26; 18/29	—	—	20/21; 26/26
Carabid beetles								
P 30	24	—	—	—	—	0/4	—	3/4
M. brassicae								
P 26 (29)	118 (120)	—	—	—	—	4/6 (2/3)	—	6/6 (1/1)

Bioassays.

The results of protective contact tests are given in Table VI. In stomach poison tests on *M. brassicae* the collected results of three trials (P 27, 28, 32) were that 3/15 larvae survived a mean dose of 0·9 mg. of the phenyl-chlorophenyl derivative though 13/13 fed with a mean of 2·4 untreated sandwiches survived; with the corresponding ethylene derivative, all five larvae survived a mean dose of 3·3 mg.

Discussion.

The monochloro and the unsymmetrical *o-p*-dichloro derivatives have activities intermediate between those of D.D.T. and the unsubstituted diphenyl trichlorethane. As the *o-p* compound is present as a concomitant product in commercial D.D.T. it cannot be considered an inactive impurity. The differences in toxicity may be ascribed again to solubility factors if asymmetry affects the surface activity of the molecule and its adsorption at the sensitive interface.

(*iv*) *The effects of modification of the -CH.CCl$_3$ group on the toxicity of D.D.T.*

Elimination of hydrogen chloride from D.D.T. to form the ethylene D.D.X. is known to remove toxic properties from the molecule. The investigation of the effects of other changes, retaining the condensed 4-chlorophenyl system, was therefore begun. Although the range of compounds necessary and the bioassay results are still incomplete, the results so far obtained merit discussion. The compounds synthesised and certain others included because of their availability and relationship to D.D.T. are as follows :—

aa bis (4-*chlorophenyl*)- *ββ dichlorethane* ($C_6H_4Cl)_2CH.CHCl_2$: by reducing D.D.T. in alcoholic solution with zinc dust and hydrochloric acid. Large prisms from alcohol, m.p. 112°. Found : C, 52·91 ; H, 3·39 ; $C_{14}H_{10}Cl_4$ requires C, 52·54 ; H, 3·15%.

aa bis (4-*chlorophenyl*)-*β chlorethylene* ($C_6H_4Cl)_2C=CHCl$: by refluxing the above ethane with alcoholic potash. Fine needles from methyl alcohol, m.p. 68°. Found : C, 59·16 ; H, 2·99 ; $C_{14}H_9Cl_3$ requires C, 59·29 ; H, 3·20%.

a chloro-aa bis (4-*chlorophenyl*)-*βββ trichlorethane* ($C_6H_4Cl)_2$ $CCl.CCl_3$: by reacting D.D.X. with chlorine in carbon tetrachloride solution. Colourless prisms from alcohol m.p. 94°. Found : C, 43·44 ; H, 2·25 ; Cl, 54·94 ; $C_{14}H_8Cl_6$ requires C, 43·23 ; H, 2·07 ; Cl, 54·71%.

4-4′*dichlorostilbene* ($C_6H_4Cl).CH = CH$ (C_6H_4Cl) : by the reduction of D.D.T. with zinc dust in boiling alcohol. Large thin colourless plates with a blue fluorescence from alcohol, m.p. 173°. Spath (*Monatsh, 35*, 473) gives m.p. 177°. Pascal and Normand (*Bull. Soc. Chim.* (4) *9*, 1062) give m.p. 153–158° ; Brand *et al* (*J. pr. 127*, 240) give m.p. 174°. Found : C, 67·44 ; H, 4·10 ; Cl, 28·32 ; $C_{14}H_{10}Cl_2$ requires C, 67·48 ; H, 4·04 ; Cl, 28·46%.

The compound, on oxidation with alkaline permanganate gave *p*-chlorobenzoic acid, m.p. 236°, and gave addition products (m.p. 221°) with chlorine and (m.p. 237° (d)) with bromine.

aa bis (4-*chlorophenyl*) *ethane* ($C_6H_4Cl)_2$ CH. CH_3 : produced with the stilbene in the above reduction of D.D.T. Stout needles from methyl alcohol, m.p. 54°. Found : C, 67·05 ; H, 4·91 ; Cl, 28·32 ; $C_{14}H_{12}Cl_2$ requires C, 66·97 ; H, 4·82 ; Cl, 28·23%.

Bis (4-*chlorophenyl*) *acetic acid* ($C_6H_4Cl)_2$ CH. COOH : by treating D.D.T. with sodium ethoxide in alcohol in a sealed tube for 24 hrs. at 120°C. Colourless prisms from chloroform m.p. 166°. Found : C, 59·77 ; H, 3·27 ; Equiv. wt. 282·1 ; $C_{13}H_9Cl_2COOH$ requires C, 59·78 ; H, 3·58 ; Equiv. wt. 281·0.

aβ bis (4-*chlorophenyl*)-*tetrachlorethane* ($C_6H_4Cl)CCl_2.CCl_2(C_6H_4Cl)$: kindly supplied by the Superintendent of the D.S.I.R. Chemical Research Laboratory, Teddington. Recrystallized from chloroform, mp.. 192° ; Kenner and Witham (*J.C.S.* 1910, 1960) give m.p. 190°C.

s-tetraphenylethane $(C_6H_5)_2CH.CH(C_6H_5)_2$: by heating the lead salt of benzilic acid as described by Kenner and Wain (*Ber. 72*, 456), white needles from methyl alcohol, m.p. 207-208°.

Tetraphenylethylene $(C_6H_5)_2C=C(C_6H_5)_2$: from diphenylmethane as described by Norris *et al* (*Ber. 43*, 1958). Recrystallized from alcohol m.p. 219-220°.

Bioassays.

The results so far obtained with the bis (4-chlorophenyl) derivatives tested are included in Table VII. To these results may be added :—

4-4′ *dichlorstilbene* : 12/13 and 23/23 woodlice unaffected at 10 mg. per filter paper (Exp. M33) ; 36/38 and 32/32 unaffected at 50 mg. per filter paper (Exp. M.38).

TABLE VII.

Bis (4-Chlorophenyl) Derivatives as Protective Contact Insecticides.

Test Organism and number	Time hr.	$(C_6H_4Cl)_2CH.CCl_3$ (D.D.T.)		$(C_6H_4Cl)_2CH.CHCl_2$		$(C_6H_4Cl)_2CH.CH_3$		$(C_6H_4Cl)_2CCl.CCl_3$		$(C_6H_4Cl)_2$ CH.COOH	$(C_6H_4Cl)_2$ C:CHCl	Control
		50·0	10·0	100·0	50·0	50·0	10·0	100·0	50·0	10·0	50·0	0mg. per 63·6 cm 2
Woodlice												
P 25	54	—	—	—	—	—	—	—	—	25/25 ; 21/22	—	20/20 ; 26/26
M 36	88	2/20 ; 10/22	—	—	—	—	—	—	25/25 ; 24/25	—	—	18/20 ; 24/24
M 37	136	0/28	—	—	—	—	—	29/30	28/29	—	—	27/27
M 38	160	—	—	—	—	29/31 ; 38/38	—	34/34 ; 30/30	—	—	—	20/21 ; 26/26
M 40	120	0/22 ; 4/27	0/31 ; 4/18	—	14/23* ; 24/27*	—	—	—	—	—	23/23 ; 30/30	28/28 ; 34/34
M 41	138	—	0/28 ; 0/16	1/34 ; 0/32	5/21 ; 26/29	—	—	—	—	—	—	23/23 ; 29/29
M 33	94	—	—	—	—	—	18/19 ; 21/23	—	—	—	—	17/17 ; 16/16

* Amount of excreta small compared to that of control.

αβ bis (4-chlorophenyl)-tetrachlorethane: 15/15 and 14/15 *Armadillidium* sp. unaffected after 66 hrs. at 50 mg. per filter paper (Exp. W.23). As a stomach poison a mean dose of 1.2 mg. proved non-toxic to four larvae of *Pionea* sp., though in a parallel test all four larvae were killed by a mean dose of 0·1 mg. D.D.T. (Exp. W24).

s-tetraphenylethane: 14/14 and 13/14 *Armadillidium* sp. remained unaffected after 46 hrs. on a deposit of 50 mg. per filter paper; similarly none of 14 and 13 woodlice were affected by the corresponding ethylene as the same dosage. On untreated paper all the control woodlice 14 and 16, remained unaffected (Exp. W.20). When tested as stomach poisons against *M. brassicae*, neither compound at an average dose of 3·3 mg. and 4·0 mg. respectively proved effective (Exp. W.29).

Triphenylmethyl chloride $(C_6H_5)_3Cl$, from laboratory stock (B.D.H.) proved like *s*-tetraphenylethane and tetraphenylethylene non-toxic to *Armadillidium* sp. dusted with a 5% powder (Exp. W.17), and when tested by the sandwich method *M. brassicae* larvae survived doses of 3·3 mg., *P. rapae* larvae survived dose of 2·5 mg. and larvae of *Pionea* sp. survived 0·7 mg. doses.

Discussion.

The loss of toxicity associated with the reaction

$$= CH—CCl_3 \rightarrow \quad = C = CCl_2 \ldots\ldots (1)$$

reveals the predominant role of the $—CCl_3$ group, but, as the addition of chlorine to D.D.X. *i.e.*

$$= C = CCl_2 \rightarrow \quad = CCl — CCl_3 \ldots . (2)$$

does not restore toxicity, it is the whole group $CH—CCl_3$ which is operative. Reaction (1) involves the loss of hydrogen chloride, and it is significant that, of the derivatives under discussion the only compounds which are toxic are those from which elimination of hydrogen chloride is possible. As the ethylene derivatives formed by this elimination are non-toxic it would seem that the cause of toxicity is the ability of the compound to liberate hydrogen chloride at the site of action within the organism.

This argument leads to the conclusion that D.D.T. is insecticidal because it satisfies three requirements :—

(1) Ability to penetrate and to concentrate at the site of action.

(2) Adequate stability to reach site of action.

(3) Ability to release hydrogen chloride when adsorbed as the sensitive interface within the organism.

A brief outline of these hypotheses was published (Martin and Wain, 1944) before the important paper by Läuger *et al* (1944) became available. In this paper the results of the Swiss investigators are given in general terms, and the following abstract, taken from Table XVI, gives the contact insecticidal action of the derivatives against unspecified insects :—

$(C_6H_4Cl)_2$	$CH.CCl_3$	highest activity.
$(C_6H_4Cl)_2$	$CCl.CCl_3$	almost without action.
$(C_6H_4Cl)_2$	$CH.CHCl_2$	moderate activity.
$(C_6H_4Cl)_2$	$CCl.CHCl_2$	good activity.
$(C_6H_4Cl)_2$	$CH.CH_2Cl$	poor activity.

The agreement between the above conclusions and those derived from tests on woodlice (Table VII) is complete, and indeed suggest a parallelism betweens degree of toxicity and ease of HCl elimination, though such a suggestion would be dangerous if it ignored the importance of the requirements (1) and (2) above. It was, apparently, the solubility factors of requirement (1), to which Läuger

et al refer by the general term of lipoid solubility, which led the Swiss investigators to suggest that the —CCl_3 group functions primarily as the component conferring lipoid solubility to the D.D.T. molecule, the toxic part of which they consider to be the bis (4-chlorophenyl) system. This hypothesis fails, however, to account for the non-toxicity of $(C_6H_4Cl)_2$ $CCl.CCl_3$, a molecule which contains both the chlorophenyl system and the —CCl_3 group.

B. Hexachlorcyclohexane.

The successful use in the field of a proprietary flea beetle dust prompted a more detailed examination of its insecticidal properties. The active component of the dust was obtained by extraction with ether and after recrystallization from alcohol a substance m.p. 145-152° was obtained which was identified as hexachlorcyclohexane (benzene hexachloride, $C_6H_6Cl_6$). As this compound exists in several isomeric forms not susceptible to easy separation or identification, no attempt was made to characterize it more closely, and this unknown mixture of stereoisomers was used in the bioassays.

Bioassays.

The results of protective contact tests are given in Table VIII, though additional tests have already been recorded in Table III.

As a stomach poison the sample of benzene hexachloride used was toxic to larvae of *P. brassicae* at a mean dose of 0·05 mg. (Exp. W.16), to larvae of *P. rapae* at the same mean dose (Exps. W.12, 14) and to larvae of *Pionea forficalis* at a mean dose of 0·04 mg. Larvae of *M. brassicae* appeared, however, to be susceptible only in the young stages; of the younger green instars only one of six surviving a mean dose of 0·24 mg., but the larger brown instars were not apparently affected. Thus in Exp. P28, all three larvae survived doses of 0·24 mg.; in Exp. P9, all five survived doses of 0.52 mg. In Exp. P14 the larvae were fed until pupation; the first weighing 0·4 g. ate 3·4 m.g.; the second (0·7 g.) pupated after 0·6 m.g.; the third (0·3 g.) died after eating 1·7 m.g., but the fourth (0·35 g.) pupated after eating 2·6 m.g. In the parallel tests with D.D.T. none of the eleven *M. brassicae* larvae of similar size survived a mean dose of 0.1 mg. D.D.T.

Discussion.

The interpretation of the results obtained with the sample of hexachlorcyclohexane is complicated by the ability of this substance to act as a fumigant (see p. 126). It is evident, however, that the substance possesses marked toxicity, though as a stomach poison, it showed a marked specificity being ineffective towards the larger Mamestra larva. In this respect it resembles rotenone (see 1943 Report, Table I). In its action on susceptible organisms, however, the toxic symptoms closely resemble those of D.D.T. poisoning, in the period of intense activity followed by a gradual loss of muscular co-ordination. Moreover, like D.D.T., hexachlorcyclohexane is capable of hydrogen chloride elimination.

C. Aromatic Nitriles.

It was observed in 1943 that *p*-tolyl cyanide had a rapid but evanescent paralytic action on earwigs and woodlice. The series has been extended to include the following :—

o-chlorobenzonitrile $ClC_6H_4.CN$ (1:2): from *o*-chloraniline by diazotisation and treatment with cuprous cyanide, needles from light petroleum, m.p. 44–45°. Henry (*Ber. 2*, 492) gives m.p. 42–43°.

p-chlorobenzonitrile $ClC_6H_4.CN$ (1:4): from *p*-chloraniline by the method described above. Needles from light petroleum m.p. 92–94°. Hantzsch and Schultze (*Ber. 28*, 673) give m.p. 92°.

TABLE VIII.

PROTECTIVE CONTACT TESTS.

Test Organism and Number	Time hr.	$C_6H_6Cl_6$				C_6Cl_6	D.D.T.				Control
		10·0	1·0	0·5	0·25	10·0	10·0	1·0	0·5	0·25	0 mg. per 63·6 cm²
Woodlice W34(25)	48(42)	—	0/19 0/18	1/8 3/10	7/13 9/15	(10/10) (8/8)	— —	8/18 3/8	10/12 9/10	15/26 12/13	15/16 (8/9) 16/16 (7/7)
Carabid Beetles W14	67	0/5 0/5	— —	— —	— —	— —	1/6 0/6	— —	— —	— —	6/6 6/6
		1·0	0·5	0·25	0·125		1·0	0·5	0·25	0·125	0 mg. per 63·6 cm²
Earwigs W36	69	0/4 0/5	0/3 0/4	0/5 0/5	2/6 1/3	— —	0/3 0/4	0/4 0/4	0/5 0/4	3/4 4/4	5/5 5/5
		5·0	2·5	1·25	1·00		5·0	2·5	1·25	1·00	0 mg. per 63·6 cm²
Soldier Beetles W27	19	0/5 0/6	0/6 0/5	0/6 0/6	— —	— —	0/6 1/6	0/6 0/6	0/9 1/9	— —	3/4 3/5
W32	19	—	—	—	0/10 0/12 0/11	—	—	—	—	—	8/8 7/7
		10·0									0 mg. per 63·6 cm²
M. brassicae P23	92	5/6	—	—	—	—	—	—	—	—	6/6
P29	120	3/3	—	—	—	—	—	—	—	—	1/1

p-bromobenzonitrile $BrC_6H_4.CN$ (1:4) from *p*-bromaniline by the method described above. Short needles from alcohol, m.p. 113°. Schopff (*Ber. 23*, 3437) gives m.p. 113°.

p-dicyanobenzene $C_6H_4(CN)_2$: by heating the diamide of terephthalic acid with phosphorus pentoxide. Fine needles from alcohol, m.p. 220–221°. Limpricht (*Annalen*, 180, 89) gives m.p. 215°. Körner and Monselise (*J.C.S.* 1876, 374) give m.p. 222°C.

s-tricyanobenzene $C_6H_3(CN)_3$: by heating the triamide of trimesic acid with phosphorus pentoxide as described by Bennett and Wain (*J.C.S.* 1936, 1111). Needles from methyl alcohol, m.p. 261–263°.

Bioassay.

Direct contact toxicity tests were made with dusts containing 5% of the nitrile taken up on a carrier (95% gypsum, 5% amorphous silica). The results are included in Table IX, which also gives the results of protective contact tests. A summary of the tests for stomach poison properties is given in Table X.

Discussion.

Although the results are too few to permit critical discussion, they suggest that further tests of nitriles as contact poisons and fumigants would be worth while, especially of the *ortho-* and *para*-substituted benzonitriles. The derivatives tested show little promise as stomach poisons.

SUMMARY.

1. The simple qualitative tests of insecticidal properties have been examined as the basis of quantitative methods by bio-assay :—

(*a*) The sandwich method for stomach poisons does not reveal the minimum lethal dose, the amount of poison ingested being determined by the speed of action of the poison and the appetite of the test organism.

(*b*) Tests of protective contact toxicity by a simplified " film " technique are amenable to quantitative development.

2. D.D.T. has been shown, by chemical and biological methods, to be compatible with alkaline components such as lime sulphur and Bordeaux mixture likely to be used in combined sprays and to be effective in the presence of petroleum oil sprays.

3. On the basis of bio-assay with D.D.T. and related compounds, it is concluded that D.D.T. is insecticidal because it satisfies the following requirements :—

(*a*) ability to penetrate to and to concentrate at a sensitive interface within the organism ;

(*b*) adequate stability to reach this site of action ;

(*c*) ability to release hydrogen chloride when adsorbed at the sensitive interface.

4. Requirement (3) (*c*) is revealed by the results of tests of compounds analogous to D.D.T., but in which the $=CH—CCl_3$ group is modified. A rough parallelism exists, in the compounds tested, between insecticidal potency and the ease of HCl elimination.

5. Requirement 3 (*a*) is operative in compounds analogous to D.D.T. but containing *p*-substituents other than chlorine ; derivatives in which this substituent is polar, *e.g.* —OH, $—O.COCH_3$ or $—CONH_2$, are less toxic than those with non-polar substituents, *e.g.* —Cl, $—CH_3$, $—OCH_3$.

6. When the *p*-substituent is halogen, a trend in toxicity is shown which is greatest in the fluorine and least in the bromine and iodine analogues.

7. For reasons 3 (*a*)—(*c*), hexachlorcyclohexane shows high insecticidal properties though the interpretation of the results obtained with an unknown mixture of its isomers is complicated by its ability to act as a fumigant. The

TABLE IX.

AROMATIC NITRILES AS CONTACT INSECTICIDES.

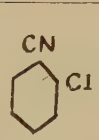
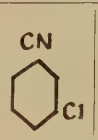
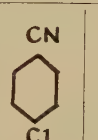
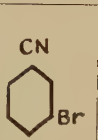
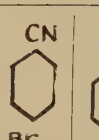
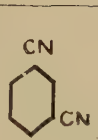
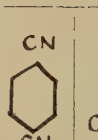
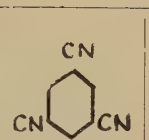
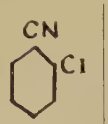
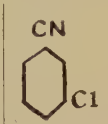
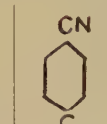
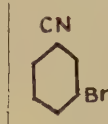
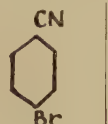
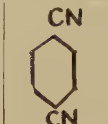
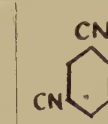
Test Organism and Number	Time hr.									Control
		Direct Contact Action (5·0 % dust)								
Woodlice— *Armadillidium* sp W13	48	0/11 0/10	8/11 10/11	1/10 0/11	1/10 3/10	7/10 6/10	16/20 11/11	10/11 10/10	— —	10/11 10/10
Other species W35	42	—	—	—	—	—	—	—	12/13 23/25	14/14 14/15
		Protective Contact Action								
		50·0			10·0	10·0				0 mg. per 62·6 cm²
Armadillidium sp W15	36	0/14 0/14	—	—	—	—	—	—	—	12/12 12/12
Other species W25	42	—	—	—	0/8 0/11	0/10 0/7	— —	— —	— —	8/9 7/7
Carabid Beetles W14	67	0/6 0/6	—	—	—	—	—	—	—	6/6 6/6
		10·0								0 mg. per 62·6 cm²
Soldier Beetles W26	20	0/7 0/7	—	—	—	—	—	—	—	7/7 6/6

TABLE X.

AROMATIC NITRILES AS STOMACH POISONS.

Bracketed figures indicate sandwiches (each of 1 mg. nitrile) eaten per larva.

Test Organism and Number	Time hr.								Control
M. brassicae									
P24	140	—	—	—	—	—	—	4/5 (4·3)	5/5 (5·7)
W29	42	—	—	—	—	—	1/3 (1·0)	—	3/4 (5·0)
P. brassicae									
W21	65	5/5 (1·4)	3/6 (1·7)	3/6 (0·5)	—	—	—	—	6/6 (5·0)
P. rapae									
W21 (24)	65 (95)	1/1 (0·6)	0/1 (0·7)	—	—	(0/1) ((0·2))	—	—	1/1 (1/1) (2·5) ((0.9))
W29 (33)	42 (118)	—	—	—	—	—	0/3 (nil)	(5/6) (0·7)	1/2 (1·2)
Pionea sp.									
W21 (24)	65 (95)	6/6 (0·5)	6/6 (1·5)	4/5 (0·4)	(4/4) ((1·2))	(0/2) ((0·1))	— —	— —	6/6 (2/2) (1·9) ((1·0))

sample examined was ineffective against larger instars of *Mamestra brassicae* larvae, though highly toxic to the other test organisms used.

8. In a limited range of aromatic nitriles, the *o*- and *p*-substituted benzonitriles gave promising results as contact poisons and fumigants, but were not stomach poisons.

Acknowledgments.

Thanks are due to Miss M. Jenkins, Miss M. O. Patton and Miss M. C. Whitwill for assistance in the biological work.

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THE HOME-PRODUCTION OF NICOTINE.

By R. F. BATT and H. MARTIN.

Summary.

Two strains of *Nicotiana tabacum* and one of *N. rustica* were grown in the glasshouse and outdoors and the yield of leaf and its alkaloid content determined. The highest nicotine content was in headed and disbudded plants of *N. rustica* grown in the glasshouse ; the highest leaf yield was from similarly grown plants of an Havana strain of *N. tabacum.* Only in these two cases were the yields of nicotine (calculated at 65·5 and 60·1 lb./acre respectively) high enough to be of promise ; plants of unrestricted outdoor growth yielded less than 10 lb. nicotine acre. In view of the labour requirements for disbudding headed plants, the home cultivation of these tobaccos for nicotine production is considered impracticable.

The nornicotine content of these plants was negligible.

Published information on the nicotine content of tobacco varieties when grown in this country is scanty and, in the trials carried out at Wye, the yields of nicotine (Garrad, 1910–12) showed wide fluctuations in the several years of the experiments, ranging from 150 lb./acre in 1911 to 35 lb./acre in 1912. When therefore suggestions were received that the importation of nicotine could be replaced by its manufacture from home-grown tobacco, it was difficult to assess the prospects. Moreover, it had been found (Markwood and Barthel, 1943) that some tobacco varieties yielded alkaloids containing a fair proportion of nornicotine which Richardson, Craig and Hansberry (1936) had found more aphicidal than nicotine. Data on the relative contents of the two alkaloids in English-grown tobaccos were not available.

Cultivation.

Accordingly tobacco seed was obtained, by the courtesy of the Director of the Royal Botanic Gardens, of two strains of *Nicotiana tabacum* and one of *N. rustica.* The seed was sown in boxes in the glasshouse on March 15. Plants

TABLE I.

LEAF AND NICOTINE YIELDS FROM TOBACCO.

	No. of Plants.	Leaf yield per plant.		Total nicotine yield.	
		Number.	Dry wt. (g.)	Per plant (g.)	per acre (lb.)
Glasshouse-grown :					
N. tabacum (Virginia strain) .. headed plants	5	8	33·3	1·383	33·2
,, ,, ,, .. unheaded plants	4	8	22·4	0·250	6·0
N. tabacum (Havana strain) .. headed plants	6	16·5	80·2	2·504	60·1
,, ,, ,, .. unheaded plants	4	18·5	51·9	0·389	9·3
N. rustica .. headed plants	7	17	60·7	2·733	65·5
,, .. unheaded plants	3	14	18·0	0·437	10·5
Outdoor-grown :					
N. tabacum (Virginia strain) .. main stem leaves	24	3	8·5	0·168	4·0
,, ,, ,, .. axillary leaves		14	8·0		
N. tacabum (Havana strain) .. main stem leaves	14	14	37·4	0·354	8·5
,, ,, ,, .. axillary leaves		Negligible			
N. rustica .. main stem leaves	21	9	15·0	0·308	7·4
,, .. axillary leaves		12*	5·1		

* Larger leaves only harvested.

to be grown in the glasshouse were pricked out into 3½″ pots four weeks later and, on May 28 were transferred one plant to a 15″ pot. Plants for growing outdoors were pricked out into boxes on March 22 and planted outdoors at 2′ x 2′ on May 17. The latter were severely attacked by slugs and the use of a Meta bait was necessary.

A number of the glasshouse plants were headed, it being known that by preventing flowering the nicotine content of the leaves is increased. The axillary buds were also removed periodically from all glasshouse plants but the outdoor plants were allowed to grow normally. It was considered that the labour required for frequent disbudding of headed plants would add so much to the difficulties of growing that prospects of home cultivation were dependent more on the nicotine production by unrestricted plants than on the amount yielded by headed and disbudded plants. Individual leaves were harvested as soon as they had yellowed ; they were allowed to wilt for six days in an untreated glasshouse and dried 4 hours at 70°C. To facilitate sampling the midribs were removed and separate samples of midrib and laminae taken for moisture and alkaloid content.

In some cases the leaves were harvested before they had yellowed, fuller particulars being :—

N. tabacum (*Virginia strain*). In the glasshouse, disbudding was begun on May 25 and five of the nine plants were headed on June 16 at an average height of 2½ ft. Leaves were picked from headed plants on August 16 and from flowered plants on August 23.

On the outdoor plants the main stem leaves were picked on September 29 in a very torn and brown condition, whereas the still green leaves from side shoots were harvested on October 5.

N. tabacum (*Havana strain*). In the glasshouse six of the ten plants were headed on June 16 at an average height of 4 ft. Leaf picking began on July 26, and was completed on September 6 before full yellowing because of a severe attack of whitefly. On the outdoor plants the amount of axillary growth was negligible and the main stem leaves only were harvested in a green condition on October 11.

N. rustica. Seven of the ten glasshouse plants were headed at 4 ft. on June 16 and the leaves were picked on August 9 and 16 from the headed plants and on August 9 and 27 from the flowered plants. On the outdoor plants the side shoots made strong growth, and when the leaves were harvested on November 1 those on the main stem were nearly all brown and withered. Only the larger of the leaves on side shoots were picked and were still green although, in order to lengthen the growing period and to save the plants from frost, the plants were " heeled in " in the glasshouse in early October. The venation of the round long-stalked leaves of this variety did not permit a clean separation of midrib and lamina, and the sample described as the former consisted mainly of petiole.

The mean yields of leaf per plant, noted in Table I, show the expected increase due to heading.

Extraction.

The alkaloids were recovered from the leaves by steam distillation from alkaline suspension of the finely-ground lamina or stalk sample, the distillate being collected in dilute acid. In all cases the quantity of distillate was large before all steam-volatile material precipitated by silicotungstic acid was recovered and the acid solution of the alkaloids was concentrated on the steam

TABLE II.

Alkaloid Content of Tobaccos.

	% alkaloid based on dry weight.			
	Nicotine.		Nornicotine.	
	Laminae.	Midrib & Stalk.	Laminae.	Midrib & Stalk.
Glasshouse-grown :				
N. tabacum (Virginia strain) .. headed	4·60	1·04	0·00	0·03
,, ,, ,, .. unheaded	1·26	0·23	0·03	0·00
N. tabacum (Havana strain) .. headed	3·76	0·39	0·05	0·02
,, ,, ,, .. unheaded	0·93	0·00	0·00	0·00
N. rustica .. headed	4·79	2·35	0·02	0·03
,, .. unheaded	2·65	0·61	0·06	0·08
Outdoor-grown :				
N. tabacum (Virginia strain) .. main stem	1·57	0·42	0·03	0·01
,, ,, ,, .. axillary	0·64	0·24	0·01	0·01
N. tabacum (Havana strain) .. main stem	1·21	0·14	0·05	0·01
N. rustica .. main stem	1·96	0·83	0·05	0·04
,, .. axillary	0·72	0·25	0·02	0·00

bath to 250 ml. from which aliquots were taken for nicotine and nornicotine content. The methods used are described by Markwood (1943). In one aliquot the steam distillation of nornicotine and other non-tertiary bases was prevented by nitrous acid treatment by which they are retained in the distillate flask as nitrosoamines. In a second aliquot the nornicotine was methylated by treatment with formaldehyde and formic acid to nicotine subsequently recovered, with the nicotine originally present, by steam distillation. Any difference found between the nicotine recovered from the second and the first aliquots may be ascribed to nornicotine.

Results.

From the analytical results, assembled in Table II, it is seen that the nornicotine content is negligible in all cases and only the nicotine content (*i.e.* the content of steam-volatile tertiary bases precipitated by silicotungstic acid) is used for the estimation of nicotine yield per plant.

The figures for nicotine (Table I) reveal the large increase obtained by heading and disbudding due to the combined effects of these operations on nicotine content and on leaf yield. But even with these precautions the highest nicotine yield (65 lb./acre assuming a 2′ x 2′ plant) is disappointingly small. Further, it is improbable that this yield would be attained in the outdoor-grown plants had they been headed and disbudded, though the unrestricted outdoor-grown plants had yields of the same order as the disbudded but flowered glasshouse plants. The operation of disbudding may then be unnecessary in flowered plants as was the case with the Havana strain of *N. tabacum* but, in headed plants, disbudding is essential otherwise flowering occurs on the side shoots. With the strains used growth must be restricted to attain relatively small nicotine yields and the labour requirements of frequent disbudding must be taken into consideration in assessing the practicability of the home production of nicotine. As under wartime conditions this labour must be diverted from food production, it is concluded that the project is unsound. Under normal conditions it may be that new strains of richer nicotine content may be introduced by breeding or selection, and it is suggested that the performance of flowered plants and the propensity of the variety for axillary growth after heading should be considered alongside nicotine content as selection criteria.

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EXPERIMENTS ON THE CONTROL OF FLEA BEETLES ON BRASSICAE IN THE WESTERN PROVINCE.

By HERBERT W. MILES, D.Sc., Ph.D.

During the period 1930-34 Petherbridge and Thomas (1) experimented with various dusts for the control of flea beetles on beds of *Brassica* seedlings in market gardens and found that satisfactory results followed the use of dusts containing derris and nicotine, while inert materials like hydrated lime were effective if used in sufficient quantities, and naphthalene applied before the seedlings emerged protected them from early underground attack. During the same period Miles (2) obtained control of flea beetles on field crops of swedes and other seedling brassicas by dusting with naphthalene-silica dust. In spite of the success obtained by these workers the use of insecticidal and other dusts to prevent loss from flea beetle attack has not become part of general farm practice. Serious loss from flea beetles usually occurs when excessively dry weather coincides with the emergence of the seedlings. Spring droughts, though frequent, do not occur every year and the farmer tends to rely on a spell of favourable weather to assist in the establishment of root crops and accepts as normal the risk of having to re-sow his fields. War conditions, however, have increased the importance of kale, swedes and turnips in the national agricultural economy, and the scarcity and high cost of seed and labour have emphasised the need for less wasteful methods of overcoming attack by flea beetles than re-sowing the crop until a satisfactory stand of seedlings is obtained.

In order to be able to meet the special war-time demands for advice on the control of flea beetles and to test the value of the newer insecticidal dusts the advisory entomologists in conference planned field experiments to be carried out in various parts of the country. To ensure that results at the different experimental centres were strictly comparable all the dusts used were obtained from a central supply and arrangements were made for them to be applied with a Starke duster specially devised for depositing a heavy dust along the rows of seedlings. The experiments were carried out on old arable fields that did not carry *Brassicae* in 1943.

Plot arrangement. An attempt was made to secure some uniformity of plot size and arrangement. As far as possible the plots were about 15 yards wide and approximately twice as long, and untreated areas of similar size were left between the plots as controls; similar areas well removed from the possible effects of the dusts were used as additional controls. The plots were so arranged that all were in approximately the same relationship to headlands, hedgesides and other sites likely to harbour flea beetles.

Treatment. The dusts selected for experiment were basic slag, P.P. flea beetle dust (No. 666) and D.D.T. (Geigy). Dusting was done in the warm part of the day when the plants were dry. The first application was made on the day that seedlings first appeared in numbers above ground, a close watch being kept so that dusting was done before flea beetle attack was appreciable. In some cases a second dusting on half of each treated plot was carried out after a short interval so that the effects of one and two dustings could be compared.

Method and rate of application. The Starke duster (Fig. 1) used for applying the dusts consisted of a container with a lid and a removeable perforated bottom plate. As it was pushed forward a sprocket fixed to the axle between the road wheels revolved and caused the compression and release of the spring of an adjustable striker. The rapid succession of blows on the perforated plate deposited the dust in a continuous band on the seedlings. The stream of dust was protected from wind by adjustable side shields. It was found difficult to apply the dusts evenly with the Starke duster, but it was estimated in Somerset that the D.D.T. (Geigy) and P.P. 666 dusts were applied at approximately 28 lbs. per acre and dressings of basic slag were correspondingly heavier.

Measurement of results. Plants and beetles were used as indicators for measuring the results of treatments. Counts were made on the day after each dusting if the weather was fine ; if not, counting was done as soon as possible in fine weather. A specially devised beetle trap (Fig. 2) that enclosed a foot-length of crop row was used when counting. The Ashton-Hayne flea beetle trap was a metal trough adjustable to the width occupied by seedlings in a row. Its sloping sides were 12″ long and 10″ deep, and were lightly coated with banding grease to trap flea beetles that were disturbed with the fingers or with a pencil. Plants in the enclosed length of row were counted and disturbed so that flea beetles on them jumped and were caught on the sticky surface of the trap where they were counted and removed for identification. On most plots 20 one-foot lengths lying in two lines of ten were examined.

Experiments in the Western Province. Experiments on flea beetle control were carried out in five counties and comprehensive data were collected in Wiltshire, Herefordshire, and Worcestershire. The crops selected for dusting were sown in April or May at a time when attack by flea beetle was expected. About the time the seedlings emerged beetles were active, and the weather was generally dry and sunny, though at some of the centres the wind interfered with flea beetle activity and prevented counts of beetles being made.

The following have contributed to the flea beetle investigations :— J. Brassington, E. L. Britton, C. M. G. Duthoit, M. J. Haddock, C. M. Harrison, A. J. Lloyd, J. Mayor, M. Miles and E. O. Murphy.

Effect of Application of Dust on Numbers of Plants. Differences between treated and untreated blocks of seedlings were generally substantial and easily visible, and plots dusted with D.D.T. (Geigy) and P.P. 666 dusts were green when little leaf tissue remained on untreated control plots. Data collected showed that differences in the numbers of plants on the various plots were not great. This suggests that the plant was not entirely satisfactory as a unit of measurement for indicating the value of treatment since no distinction was made between healthy vigorous plants and those with cotyledons and leaves seriously reduced in area through flea beetle attack. Another factor that complicated the measurement of results of dusting was the slow germination of the seed. As a result of this, the series of observations on particular plots were not necessarily continuous observations on the progress of particular seedlings.

A summary indicating the comparative efficiency of the dusts used in these experiments is given in Table I. Here the index number of 100 was used to indicate the numbers of plants on control plots and the indices of efficiency for the various dusts were calculated from a comparison of the numbers of plants on the treated plots with those on related control plots.

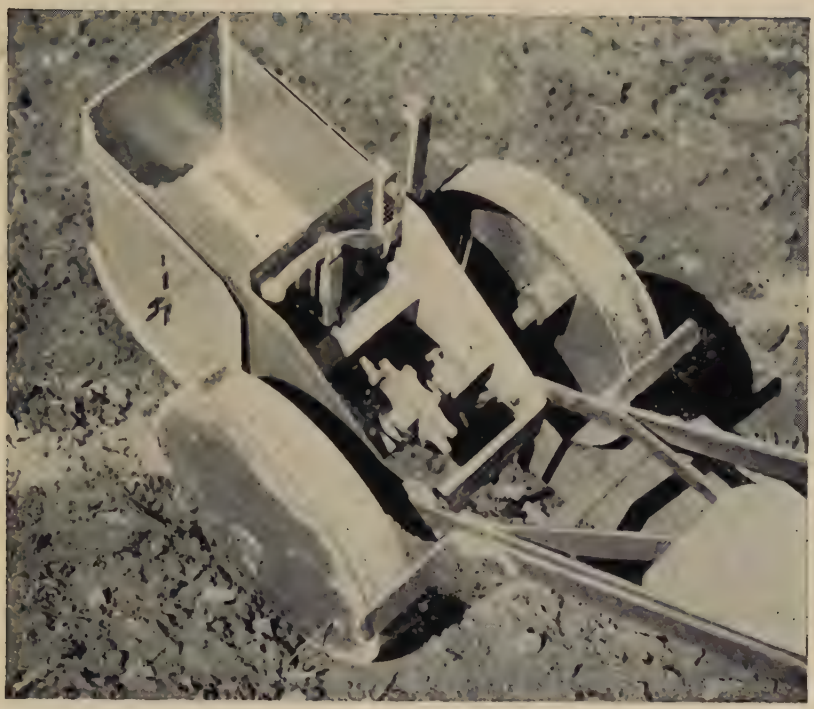

Fig. 1. Starke duster showing dust chamber, spring adjustment lever and sprocket.

Fig. 2. Flea beetle trap in position.

Fig. 3. Starke duster with lid and wind shield in position.

TABLE I.

Treatment	Comparative efficiency of dusts on plots examined		
	One day after dusting	2–8 days after dusting	9–16 days after dusting
D.D.T. (Geigy)	104	83	189
P.P. 666	112	73	150
Basic Slag	113	100	55
Control	100	100	100

The figures showing the comparative efficiency of the dusts at various times after dusting are interesting. Only small differences between numbers of plants on treated and untreated plots were expected when the plots were examined on the day following dusting, but the figures suggest that untreated plots had lost approximately 10 per cent. more seedlings through flea beetle attack than the treated plots in the critical period immediately following emergence. Plan counts 2-8 days after dusting suggest that D.D.T. (Geigy) and P.P. 666 dusts as used may have had some phytocidal action as the numbers of plants on treated plots were depressed in relation to the numbers on control plots and those treated with basic slag. This depression in the numbers of plants was only temporary and may have been associated with the effect of either the insecticides or their carriers on plants already bitten by flea beetles and exuding sap from the points of injury. Observations 9-16 days after dusting show that plots dusted with D.D.T. (Geigy) and P.P. 666 dusts had substantially more plants than those left untreated and any phytocidal action that may have occurred was fully compensated by the protection given to plants during their subsequent growth. Two weeks after emergence seedlings of *Brassica* are usually in the rough leaf stage and no longer likely to succumb to flea beetle attack.

Effect of Application of Dust on Numbers of Beetles. The counting of flea beetles about the plots was hampered by the extreme sensitivity of the beetles to weather conditions. On cloudy, windy or wet days the beetles were not found on the plants and in consequence counts of beetles could not be made at the same time as counts of plants, as had been intended. Observations on the occurrence of beetles on the dusted plots were also complicated by the fact that as the plants on the untreated areas were destroyed the numbers of beetles on these areas diminished and there was some migration to treated areas in the vicinity. This was particularly noticeable in a field at Cannington, Somerset, when, 19 days after dusting with D.D.T. (Geigy) there was an average of 3 plants and 30 beetles per foot on the treated area while on the untreated portion of the field the plants had been completely destroyed by flea beetles and consequently beetles were no longer present.

Data collected during experiments indicated that D.D.T. (Geigy) and P.P. 666 dusts reduced the flea beetle population. This was verified in the case of D.D.T. (Geigy) dust by observations at Long Ashton. Three plots of seedling *Brassicae* were dusted and three were left untreated. A few hours after dusting, 10 one-foot lengths of crop row were examined on each plot for the occurrence of beetles and similar examinations were made daily until weather interfered with beetle activity. The following data were collected :—

TABLE II.

Date	Numbers of beetles per 10 feet of drill row					
	Treated plots			Untreated plots		
	a	b	c	a	b	c
11.5.44	1	1	1	27	9	45
12.5.44	0	0	0	32	7	26
13.5.44	0	0	0	12	8	7
15.5.44	0	0	0	12	11	16

Effect of Dusting on Intensity of Flea Beetle Attack. Since comparisons of numbers of plants on the various plots gave no clear indication of the effect of dusting, and beetle activity was too irregular and uncertain for satisfactory series of counts to be secured, some of the observers supplemented their records with measurements of the intensity of flea beetle attack. In Worcestershire observations were made on the numbers of plants showing signs of beetle injury on the day after the application of dusts. Figures given in Table III are the averages obtained from 192—240 one-foot lengths of crop row.

TABLE III.

Time of examination	Treatment	Plants per foot	% plants free from attack
One day after first dusting	D.D.T. (Geigy)	2·2	59
,, ,, ,,	P.P. 666	2·2	63
,, ,, ,,	Basic Slag	2·3	58
,, ,, ,,	Control	2·0	24

Figures given in Table III serve to indicate the extent of protection afforded by D.D.T. (Geigy) and P.P. 666 dusts and basic slag twenty-four hours after application. As was already noted in Table I the number of plants on untreated plots was approximately 10 per cent. less than on treated plots, but the degree of protection was more clearly shown by comparing the percentage of plants free from flea beetle injury. On treated plots approximately 60 per cent. of the plants were free from injury by flea beetles, while on the control plots only 25 per cent. were free from attack.

In Wiltshire observations on the intensity of flea beetle injury consisted of counts of injured cotyledons and leaves, and some of the collected data are given in Tables IV and V.

Data in Tables IV and V give further evidence of the protection afforded by the use of dusts on seedling *Brassicae*. In Tables I, III and IV D.D.T. (Geigy), P.P. 666 dust and basic slag are shown to give approximately the same degree of protection to seedling *Brassicae* for the first twenty-four hours, but from the data in Table V it would appear that six days after the application of dusts the plants on untreated plots had twice as many attacked leaves as plants on plots dusted with D.D.T. (Geigy) and P.P. 666.

TABLE IV

Time of examination	Treatment	No. leaves examined	No. leaves punctured	No. leaves eaten	% leaves undamaged
One day after first dusting	D.D.T. (Geigy)	282	21	10	89
,, ,,	P.P. 666	234	22	4	89
,, ,,	Basic Slag	268	21	21	84
,, ,,	Control	656	136	72	68

TABLE V.

Time of examination	Treatment	No. plants examined	No. leaves punctured	No. leaves eaten	No. attacked leaves per plant
6 days after first dusting	D.D.T. (Geigy)	64	43	18	·95
,, ,,	P.P. 666	66	43	15	·89
,, ,,	Basic Slag	94	115	58	1·86
,, ,,	Control	138	140	136	2·00

Summary and Recommendations. Experiments on the use of D.D.T. (Geigy), P.P. 666 and basic slag for the protection of seedling *Brassicae* from attack by flea beetles have shown that an application of these dusts checks the loss of plants and is associated with a reduction in the proportion of plants showing injury by beetles.

Examination of plots on the day following the application of dusts showed that for the first twenty-four hours after dusting D.D.T. (Geigy), P.P. 666 and basic slag afforded approximately the same degree of protection to the plants (Tables I, III and IV).

Examination of the plots 2 -8 days after dusting suggested that D.D.T. (Geigy) and P.P. 666 dusts may have had some phytocidal action on the seedlings (Table I), but this was compensated by the protection from flea beetle injury afforded by these dusts during later stages of growth (Tables I and V).

Examination of plots 9—16 days after the application of dusts showed that more plants were established on plots treated with D.D.T. (Geigy) and P.P. 666 dusts than on plots treated with basic slag and on untreated plots.

The need for a second dusting appeared to be local and seasonal. One application seemed sufficient in the case of D.D.T. (Geigy) and P.P. 666 dust, but the failure of basic slag to give adequate protection to the crop after a few days suggests that where this substance is used for crop protection several applications at short intervals are required in order to obtain a satisfactory establishment of the seedlings.

There was some evidence that D.D.T. (Geigy) and P.P. 666 dusts killed the flea beetles present on the seedlings when they were dusted and protected them against further attack.

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THE CONTROL OF BLACK CURRANT LEAF SPOT BY DITHIOCARBAMATE SPRAYS AND THE EFFECTS OF SPRAY RESIDUES ON THE CANNED FRUIT.

By R. W. MARSH and D. DICKINSON.

INTRODUCTORY.

The routine control measure for use against black currant leaf spot caused by *Pseudopeziza ribis* is a Bordeaux spray applied immediately after picking (Marsh and Maynard, 1930). If however the defoliation due to the disease has already made considerable progress by the time picking has started, the efficacy of a post-cropping spray treatment is much reduced. To control such an early attack it is obviously desirable to apply a fungicide to the bushes in late June or early July, *i.e.* when the fruit is ripening. Such treatment raises serious problems since it is most undesirable that black currants intended for processing should retain any copper residue. Even a trace of this element catalyses the oxidation of vitamin C. The use of copper sprays on black currant fruits at any stage of development is therefore inadmissible.

The application of lime sulphur to black currants during the summer is also open to objections. First, it is known that lime sulphur is phytocidal to black currant foliage at this season. Secondly, any trace of sulphide sulphur on fruits used for canning promotes corrosion of the containers leading to " hydrogen swells " and confers an undesirable flavour on the product (Adam, 1938).

In the attempt to select a satisfactory material for use as a pre-cropping spray on black currants, special attention was paid to the dithiocarbamates which have been shown in laboratory tests to be promising fungicides (Parker-Rhodes, 1943). Ferric dimethyldithiocarbamate is the active ingredient of the product known as Fermate which has given good results in the U.S.A. against apple scab, apple rust and peach brown rot (Hamilton *et al*, 1943). It has not hitherto been tested on black currants.

Preliminary laboratory trials were made with the dithiocarbamates readily available, namely ferric pentamethylenedithiocarbamate and ferric dimethyldithiocarbamate. The latter proved superior as a fungicide, and in laboratory leaf tests at 2 gm. per litre it inhibited the germination of *Pseudopeziza ribis* conidia on leaves of black currant. It was therefore chosen for test in the field as a pre-cropping spray.

As no spray could be recommended for black currants unless the residue were without deleterious effect on the processed product, canning trials were carried out with the sprayed fruit and the results of these trials are given following those on leaf spot control.

In addition to the experiment on a pre-cropping spray, a subsidiary trial was made of post-crop treatments, comparing the standard Bordeaux mixture with preparations of copper sebacate, which had shown promise in a preliminary trial (Marsh, 1944).

SPRAYING TRIALS.

(By R. W. Marsh).

Plots.

The trial was carried out on a plantation of Baldwin black currant bushes at Long Ashton set out in 1940 at 6 ft. on the square. From south to north

the bush rows were numbered 1 to 32, inclusive, each row being of seven bushes. The plot was generally even in growth, but the six rows at the southern end, sited on a patch that lay wet after heavy rain, were slightly less vigorous than the remainder. The bushes were very little affected by the frosts of May 1944 and their growth and cropping during the season were normal.

Materials.

Ferric dimethyldithiocarbamate. A sample of ferric dimethyldithiocarbamate was kindly supplied by Robinson Brothers, of Birmingham. The material was in the form of a black powder which rapidly settled out on suspending in water. For use as a spray it was therefore mixed in the proportion of 2 lb. of the dithiocarbamate to 1 pt. ester salts,* the whole being diluted to 100 gall. when required for spraying.

" *Fermate.*" Material of Fermate was obtained by courtesy of Messrs. Plant Protection Ltd. This was said to contain 60 per cent. ferric dimethyldithiocarbamate compounded with a spreader. At a concentration of 2 lb. per 100 gall. it readily formed a stable suspension in water.

Copper sebacate. Copper sebacate was specially prepared for this investigation by Messrs. Boake, Roberts, whose assistance is gratefully acknowledged. As previously recorded, this material needs to be compounded for use as a spray. In the present trial, 4 lb. sebacate was pasted up with ½ lb. Agral L and a little water, the whole being diluted to make 100 gall. of spray.

Copper sebacate dust. A dust was made at Long Ashton by grinding together in a ball mill 4 lb. sebacate, 3 lb. silica and 3 lb. gypsum. The sebacate and silica were first ground together ½ hr., then the gypsum was added a little at a time with further grinding, and the whole finally ground for 1 hr. A moderately fine, free-flowing dust resulted.

Bordeaux mixture. A standard Bordeaux mixture (4 lb. copper sulphate, 10 lb. hydrated lime, 100 gall. water) was prepared, this having approximately the same copper concentration as the sebacate spray.

Applications.

Pre-cropping. The pre-cropping application was made on July 6th, 1944, *i.e.* 15 days before picking. Rows 9–16 were sprayed with Fermate at 2 lb. per 100 gall., approximately 45 gall. being used for the 56 bushes. The application was made at 200 lb. pressure, using a 3-nozzle broom. On the same day, rows 25–32 were sprayed in the same manner with the ferric dimethyldithiocarbamate (including ester salts) at 2 lb. per 100 gall. Approximately 40 gall. of this spray was used, the spreading being slightly better than in rows 9–16 and the spray deposit on drying less conspicuous. Rows 1–8 and 17–24 received no pre-cropping spray.

The weather was favourable for spraying and continued fine for eight hours afterwards, when there was a heavy thunderstorm. The black spray deposit remained visible on the leaves for several weeks, but it was not apparent on the black skin of the fruits without careful examination.

Post-cropping. The post-crop sprays, applied on July 27th, were replicated over the pre-cropping treatments as follows :—

Bordeaux 4–10–100	on	rows	7, 8, 13, 14, 19, 20, 25, 26.
Sebacate spray	,,	,,	3, 4, 11, 12, 17, 18, 29, 30.
Sebacate dust	,,	,,	1, 2, 9, 10, 21, 22, 27, 28.
No post-crop treatment	,,		5, 6, 15, 16, 23, 24, 31, 32.

* An 11% solution of sodium secondary alkyl sulphates.

The method of application of the sprays was as before; the dust was applied with a hand-operated rotary blower. Weather conditions were satisfactory for spraying, but occasional gusts handicapped the dusting operation. The amount of material used for each treatment (56 bushes) was 35–40 gall. of spray; 5 lb. of dust. Rain followed the same night but did not cause any obviously heavy loss of deposit either from the sprayed or the dusted bushes.

Results.

Leaf spotting caused by *Pseudopeziza* was first noted in the plot on June 21st on old leaves at the bases of the fruit trusses. By July 7th it had not spread noticeably. Detailed records of defoliation due to *Pseudopeziza* were made on July 20th (one day before picking), August 16th, September 5th, September 26th and October 13th. At each count every bush was allotted a number ranging from 0–10 according to a visual estimate of the proportion of foliage it retained, *e.g.* a bush completely defoliated by *Pseudopeziza* attack was rated 0, a bush retaining seven-tenths of its foliage was rated 7, and so on. All estimates were made by the writer. In Table I the figures obtained on September 26th for each 2-row plot are summed and expressed as a percentage foliage retention figure for that plot.

TABLE I.

Experimental Results.

Percentage foliage retention 26th September, 1944.

	Following no pre-crop spray.		Following pre-crop spray.	
Post-crop treatments:				
Bordeaux	57	66	70	81
Sebacate spray ..	46	56	72	76
Sebacate dust ..	34	46	66	76
Nil	24	21	66	73

The above results have been subjected to a statistical examination for which thanks are due to Dr. H. Martin. The foliage retention rating for each bush was transformed to the $\sqrt{(x+\frac{1}{2})}$ value, and the pre-cropping treatment was placed in one of the two categories, pre-crop spray or no pre-crop spray. The analysis of variance and the transformed means of the bush estimates are given in Tables II and III respectively.

TABLE II.

Analysis of Variance.

	D/F	Variance.
Main blocks	1	1·6150
A. Pre-crop *v.* no pre-crop	1	20·7889
B. Post-crop	3	3·2787
Interaction A x B	3	1·4458
Remainder	215	0·0849
	223	

TABLE III.

TRANSFORMED MEANS OF BUSH ESTIMATES.

	Post-crop treatments.				
	Bordeaux.	Sebacate spray.	Sebacate dust	Control.	Mean.
No pre-crop spray	2·5650	2·3418	2·0836	1·6279	2·1546
Pre-crop spray ..	2·8343	2·8150	2·7543	2·6518	2·7638
Mean ..	2·6996	2·5784	2·4189	2·1398	

Significant difference required for post-crop sprays .. 0·1107
" " " " pre-crop " .. 0·0783
" " " " interaction .. 0·1565

The significant differences between treatments thus established are as follows (using the sign < to mean " significantly better than ").

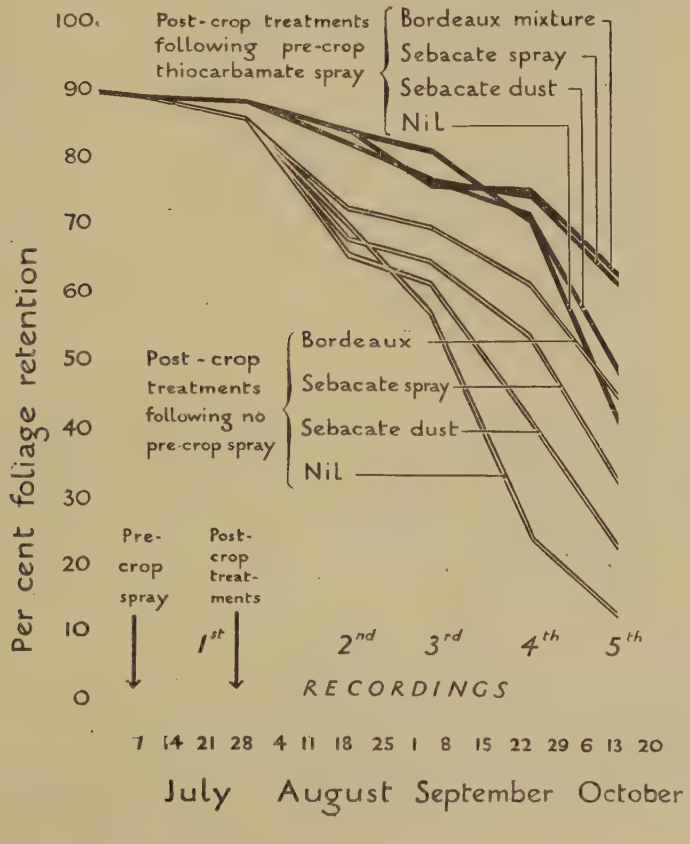
(1) Pre-cropping spray < no pre-cropping spray.

(2) Where the post-cropping sprays follow the pre-cropping spray, Bordeaux < Control and Sebacate spray < Control.

(3) Where the post-cropping sprays follow no pre-cropping spray, Bordeaux < Sebacate spray < Sebacate dust < Control.

The course of the disease throughout the whole period of recording is displayed in Figure 1.

FIG 1 BLACK CURRANT LEAF SPOT TRIAL 1944: PROGRESS OF DEFOLIATION IN RELATION TO SPRAY TREATMENTS



The results demonstrate clearly the value of ferric dimethyldithiocarbamate (Fermate) in the control of black currant leaf spot. Further, the records emphasise the superior value of the pre-cropping spray as compared with the post-crop treatments. The single application of the dithiocarbamate spray in early July, with no subsequent treatment, maintained until early October a higher level of control than was attained by any post-cropping treatment. The supplementing of the pre-cropping spray by post-cropping treatments with Bordeaux and sebacate sprays showed advantages only at the end of the season.

Where no pre-cropping spray was applied, the value of the post-cropping sprays from mid-August onwards was in the order Bordeaux, sebacate spray, sebacate dust. By early October the plots given only a post-cropping spray with Bordeaux showed approximately the same level of defoliation as those sprayed pre-cropping only with dithiocarbamate. Throughout July, August and September, however, the pre-cropping spray maintained a better control than the post-cropping Bordeaux application, and it has been shown that the degree of retention of foliage during these months is reflected in the vigour and cropping power of the bush in the succeeding season.

Processing Experiments.

Methods.

On July 20th, 12 lb. of black currants were picked at random from the bushes sprayed July 6th with Fermate. A corresponding weight of unsprayed fruit was picked from the adjoining block. The writer is indebted to Mrs. Croxall of the Domestic Preservation Department at Long Ashton, for carrying out the canning of these samples. Fourteen cans (size A2) were prepared as under :—

Treatment before picking.	Treatment after picking.	No. of Cans.	Treatment Code.
Unsprayed	Rinsed cold water	5	A
,,	Unrinsed	2	B
Sprayed (Fermate)	Rinsed cold water	5	C
,,	Unrinsed	2	D

The weight of fruit placed in each can was 390 gm : 212 cc. boiling syrup (30° Brix) was poured over and the cans sealed at once with a " Williamson " hand sealer, then sterilised. The cans were stored at Long Ashton until August 30th, when they were taken to Campden Research Station and stored at normal temperatures for examination as required.

INVESTIGATIONS ON THE CANNED FRUIT.

(By D. Dickinson*.)

Examination.

At intervals, cans were opened and examined for discoloration of the fruit or staining of the can, and the hydrogen sulphide present in the contents was determined (Dickinson, 1945). The results are shown in Table IV.

* Fruit and Vegetable Preservation Research Station, Campden.

TABLE IV.

Storage Period (weeks)	Treatment Code	H_2S found	Discoloration (fruit)	Staining (can)	Corrosion of can
8	A	nil	None	None	
	B	nil	None	None	
	C	nil	None	None	
	D	nil	None	None	
16	A	nil	None	None	
	C	nil	None	None	
24	A	nil	sl. blue	None	Body lacquer pin-holed and seams visibly corroded
	C	nil	None	None	Moderate on seams
	D	nil	sl. blue	None	Same as A above

These show that the small, but unknown, quantity of spray residue on the fruit did not cause any staining of the can, nor discoloration of the contents. Whatever the chemical composition of the spray residue when the fruit was canned, it was not converted to hydrogen sulphide within six months at normal temperatures. This may mean either that the spray residue was stable and without effect on the corrosion processes, or that the amount of spray residue was so small that its effects were not detectable.

Some Properties of Ferric Dimethyldithiocarbamate.

Solubility.

In order to investigate the effect of ferric dimethyldithiocarbamate in laboratory corrosion tests it was necessary to determine its solubility. This was found to be only 13 mgm. per litre in distilled water at 19° C., but it was much greater (30 mgm. per litre) in a citrate buffer solution of pH 3·0 at the same temperature. It was found to be slightly more soluble in black currant juice (37 mgm. per litre).

Decomposition by Acid Solutions.

Distillation of the compound with a buffer solution at pH 3·0 did not result in the liberation of hydrogen sulphide. Carbon disulphide was liberated, as was readily evidenced by the odour of the distillate. The course of the decomposition was the same in the presence of black currant syrup. It appears likely that under these conditions the compound splits into CS_2, $(CH_3)_2{\cdot}NH$, and the ferric salt of the acid responsible for the decomposition.

Effect on the Corrosivity of Black Currant Juice.

A sample of black currant juice in which the pectin had been degraded by enzyme treatment was kindly supplied by Dr. V. L. S. Charley, of Messrs. H. W. Carter & Co., Ltd., Bristol. It contained approximately 13% of dissolved solids and was used to determine the effects of pure and commercial ferric dimethyldithiocarbamate on the corrosivity of black currant juice. The commercial compound contained 5% of solid sulphite lye. The simplified

method for the determination of comparative corrosivity was used (Dickinson, 1943). The comparative corrosivity is the corrosive power of the juice expressed as a percentage of the corrosivity of a standard hydrochloric acid solution. The results, given in Table V, show that neither form of the compound accelerates the corrosion of steel plate by the juice under the conditions of the test, from which it is concluded that there is little fear of accelerated corrosion occurring in the canned product as a result of spray residues of these materials.

TABLE V.

Corrosive liquid.	Comparative Corrosivity.	Mean.
Blackcurrant juice	1·08, 1·06, 1·12, 1·30, 1·18, 1·19	1·16
Blackcurrant juice saturated with the pure compound	1·02, 1·33, 1·05, 1·00, 0·62, 0·83	0·98
Blackcurrant juice, plus 30·4 mgm/l. of commercial ferric dimethydithiocarbamate	0·34, 0·55, 0·56, 0·50	0·49

Effect on Ascorbic Acid.

Preliminary experiments have shown that the compound interferes quantitatively in the determination of vitamin C by titration with 2:6 dichlorophenol-indophenol, giving results higher than the true values; this effect is of no practical importance provided that the quantity of spray residue is small. On heating a saturated solution of the compound in citrate buffer (pH 3·0) with pure ascorbic acid, evidence of oxidation of the vitamin by the compound was obtained.

DISCUSSION.

The results of the spraying trials indicate that ferric dimethyldithiocarbamate applied in early July is effective in the control of black currant leaf spot. The practicability of this spraying treatment depends upon the absence of deleterious effects arising from the residue on the processed fruit. Although the results of the experiments described above indicate that spray residues from ferric dimethyldithiocarbamate on black currants are not likely to have any obvious effect on the canned product, either as regards discoloration of can or contents, or acceleration of corrosion, they must be subject to the reservation imposed by the fact that the quantity of residue introduced into the cans is not known. (Approx. 100 g. of the canned product on distillation in steam yielded a distillate which gave a barely detectable brown colour on adding a dilute copper solution.) Owing to the fact that decomposition of the material in boiling black currant juice liberates carbon disulphide—a substance which is both toxic and pungent—it is desirable that the maximum possible quantity of spray residue should be known. The possibility of danger from this source may then be assessed with greater confidence.

Similarly, the effects on vitamin C and on its estimation are not likely to be serious provided that the quantity of residue on the canned fruit is small.

The important figures still to be ascertained include the retention and tenacity of the spray deposit under a wide range of conditions, the extent of breakdown of the residue by weathering, and the effect of known quantities of the spray residue on corrosion by the canned currants. Trials to elucidate these points are planned for 1945.

SUMMARY.

1. Black currant leaf spot was satisfactorily controlled by spraying the bushes, 15 days before picking, with ferric dimethyldithiocarbamate preparations. The level of control was slightly raised by a supplementary post-cropping spray with either Bordeaux mixture or copper sebacate.

2. Post-cropping sprays alone were generally inferior to the pre-cropping spray in leaf spot control. The effectiveness of post-cropping treatments was in the order, Bordeaux mixture, copper sebacate spray, copper sebacate dust.

3. Storage trials with canned fruit bearing the dithiocarbamate spray residue showed that the amount present caused neither staining of the can nor discoloration of the contents.

4. Further tests showed that ferric dimethyldithiocarbamate did not accelerate the corrosion of steel plate by black currant juice.

5. Preliminary investigations indicate that ferric dimethyldithiocarbamate has some effect in promoting breakdown of vitamin C and in interfering with the estimation of this vitamin. It is unlikely that these effects will be of sufficient magnitude to be serious on the canned sprayed currants, but further investigations are in progress.

Acknowledgments.

The authors wish to express their gratitude for the judicious criticism and assistance given by Mr. W. B. Adam in the course of these investigations.

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A FIELD TRIAL ON THE COMBINED CONTROL OF CODLING MOTH AND BROWN ROT OF APPLES.

By S. H. BENNETT, H. G. H. KEARNS & R. W. MARSH.

Serious losses due to brown rot of apples occur every year in the late summer, and the disease was unusually prevalent in 1943. The causative fungus (*Sclerotinia fructigena*) enters the fruit through breaks in the skin, frequently attacking apples invaded by the larvae of the codling moth, *Laspeyresia* (*Cydia*) *pomonella*. A protective insecticide-fungicide spray applied in late June therefore presents possibilities of controlling brown rot both directly and indirectly. If an acaricide could also be applied at this period it would assist in the control of red spider mites which escaped control at the petal fall spraying. It is a matter of general experience that lime sulphur washes on apples in June have little effect in controlling brown rot. Therefore in the trial described below the fungicides selected were copper and dithiocarbamate washes, the latter having been recommended for the control of cherry brown rot in U.S.A. (1). These fungicides, unlike lime sulphur, are not acaricides, so it was necessary to use them with an oil emulsion to ensure some control of Red Spider. The insecticides chosen for codling moth control were lead arsenate (the standard application) and, for comparison, D.D.T.

It must be stated at this point that, owing to the low infestations of codling (less than 2 per cent.) and the almost total absence of red spider on the trial plots in 1944, no results on the control of these pests were obtained in this experiment. The observations recorded are confined to those on codling moth prevalence, spray damage and brown rot control.

Materials.

The three spray mixtures used in the trial were as follows :—

Wash A	Bouisol	4 pt.
	Grade G oil emulsion ..	1 gal.
	Lead arsenate	3 lb.
	Water to	100 gal.

The oil emulsion concentrate contained 67% Grade G oil (of 98% u.s.r.), emulsified with half its volume of 20% solution of sulphite lye (60° Tw.).

The fungicide used was a proprietary copper oxychloride (16% Cu) processed with sulphite lye. This material was chosen in preference to Bordeaux Mixture in the hope that it would be less damaging.

Wash B	Bouisol	4 pt.
	Grade G oil emulsion ..	1 gal.
	D.D.T.	1 lb.
	Water to	100 gal.

The fungicide and oil emulsion were as in Wash A. To prepare a sprayable suspension of D.D.T., the required amount (1 lb.) was first dissolved in a mixture of 3·5 lb. acetone and 5 lb. carbitol containing 0·5 lb. Sulphonated Lorol T.A. This stock solution was added to the spray tank just before application.

Wash C	Fermate	2 lb.
	Grade G oil emulsion ..	1 gal.
	D.D.T.	1 lb.
	Water to	100 gal.

Fermate is a proprietary product supplied by Messrs. Plant Protection Ltd., and stated to contain 60% ferric dimethyldithiocarbamate. The other materials were as in Wash B. The Fermate was pasted up in a ball mill with the oil emulsion for 2½ hr. to form a smooth cream before dilution.

Layout of Plots.

The trial was carried out in a Worcestershire plantation of cordon apples of unusual age and height. These cordons were approximately 30 years old and 10—14 ft. high. They were planted 3 ft. apart in 36 rows of 200 per row, the distance between rows being 8 ft. Two rows of the variety Cox's Orange Pippin, the sixth and eighteenth respectively from the western side, were selected for the experimental washes. These trees had received the normal routine lime sulphur washes for dessert apples up to the petal fall stage and were bearing a clean, moderately heavy crop in June. Each of the two rows was divided into two, and the four treatments (Washes A, B, and C and the Control D) were randomised in each half-row. Every treatment was thus replicated four times on units of 25 cordon trees.

Observations on the Codling Moth Attack.

Observations on the intensity of occurrence of the moths in the plantation were made every second day from June 14 to July 28, so that the relationship between the peak period of oviposition and date of spraying could be recorded. The trapping method employed was the suspending of open-topped 7 x 4 x 1 in. metal trays at various heights among the cordons in proximity to the rows

used for the spray trial. The trays were baited with 1 part by volume of beet molasses in 9 parts of water, the mixture being fermented with baker's yeast added at the rate of $3\frac{1}{2}$ g. per litre. The bait was replaced every third day except in very hot weather when it had to be replaced more frequently to compensate for evaporation.

The moths were found floating on or stuck to the bait and occasionally some were removed by birds. It was evident that only an occasional egg had been laid before trapping started, and a few more were laid by a small second brood in August, after trapping was discontinued. The number of moths captured in the period June 14 to July 28 is given below : the totals of male and female moths were approximately equal.

TABLE I.

Codling Moth Trapping Records.

14 June—28 July, 1944.

	June								
Date	14	16	18	20	22	24	26	28	30
No. of Moths ..	0	0	6	9	7	35	28	0	6

	July													
Date	2	4	6	8	10	12	14	16	18	20	22	24	26	28
No. of Moths ..	13	6	15	11	18	1	7	7	14	14	6	5	1	0

These catches are to be regarded as giving only an indication of the variations in population intensity over the given period. It was clear that the egg-laying period of the first brood of moths extended over several weeks.

Applications.

All washes were applied on June 30, this being selected as the date most likely to ensure the optimum control of codling moth obtainable by a single application. Applications were made with three-nozzle brooms at 400 lb. per sq. inch pressure, and the work was done most thoroughly. Owing to the accessibility of every part of the cordons, the cover given was heavier and more nearly complete than in normal commercial spraying. Approximately 75 gal. was used on each plot of 25 cordon trees.

Spray Damage.

The Fermate-oil wash left a most conspicuous black residue on the leaves and fruit which persisted on the apples for the rest of the season as unsightly dark blotches. The plots sprayed with the mixtures containing copper and oil exhibited serious defoliation within three weeks of spraying and disfiguring russetting on much of the fruit. (See Table II.)

The records of defoliation and of russetting made on October 2nd are as follows :—

TABLE II.

Spray Damage Records.

Treatment	Leaf Damage	Fruit Damage
A (oil-Bouisol-arsenate)	40–50% defoliation	34·4% disfiguring russetting
B (oil-Bouisol-D.D.T.)	90% defoliation	35·8% „ „
C (oil-Fermate-D.D.T.)	Slight defoliation on laterals	nil
D (Control)	nil	nil

The effects of defoliation on the A and B plots were also reflected in the diminution of fruit size. (See Table III.)

Brown Rot Control.

As previously noted, no codling attack took place on the trial plots in 1944. Infections by scab were also negligible, so the opportunities of entry for the brown rot fungus were scanty. The first infections were seen in August and the attack developed slowly, never reaching epidemic proportions. Final counts were made on October 10 on random samples of 250—300 fruits picked from each plot (*i.e.* > 1,000 per treatment). Records were made of the number of fruits infected with brown rot and the mean weight per fruit. The results are assembled in Table III.

TABLE III.

Records of Infection and Fruit Size.

Treatment	Mean percentage Brown Rot	Mean weight per fruit (g.)
A	2·05 ± 0·52	69 ± 2·68
B	2·15 ± 0·73	62·75 ± 2·93
C	2·20 ± 0·69	76·75 ± 3·43
D	10·25 ± 0·92	84·75 ± 3·42 (Significant difference—9·64)

Significant differences in mean weight of fruit exist between A and D, B and D, and B and C.

Samples of fruit from each treatment were kept in ordinary store until December, but no material increase of brown rot infection developed.

Discussion.

It is apparent that all three fungicidal treatments reduced a brown rot infection of 10 per cent. by approximately four-fifths, there being no significant difference between the fungicidal effects of the different washes. While the attack of brown rot in this experiment was relatively light, the result suggests that the control of this disease by summer spraying merits wider trial.

In phytocidal effect the difference between the Fermate and the copper sprays was considerable. The anticipation that the application of copper as oxychloride might prove much safer than its use as Bordeaux mixture was not fulfilled. The oxychloride spray proved much too damaging to be recommended for summer treatment on Cox, although it is possible that the very heavy application and the presence of the oil may have augmented the damage. The numerous records that have been made of copper damage to Cox might suggest that no copper spray could safely be used on this variety after April. However, in another experiment, carried out at Long Ashton in 1944, it was noted that copper sebacate, used as a summer spray on Worcester Pearmain, was almost without phytocidal action on this variety, whereas Bordeaux mixture used for comparison caused widespread leaf drop and fruit russetting. Large-scale trials with copper sebacate on Cox have not yet been made.

The leaf damage caused by the Fermate-oil spray in the Worcestershire trial was negligible, but the disfigurement of the fruit by the spray residue was serious. The tenacity of the deposit was enhanced by the oil carrier, but trials elsewhere have shown that Fermate used with a water-soluble wetter

still leaves visible traces on apples after many weeks. It appears likely that for use on apples it will be necessary to select a material combining the fungicidal value and safety of the thiocarbamate group with a non-objectionable spray residue.

Summary.

1. Cordon trees of Cox's Orange Pippin heavily sprayed at the end of June with washes containing either copper oxychloride (Bouisol) or ferric dimethyldithiocarbamate (Fermate) showed approximately 2 per cent. fruit infection with brown rot in October as compared with 10 per cent. in the control plots.

2. The washes containing copper oxychloride caused serious defoliation and russetting: the Fermate wash was not phytocidal but left a tenacious disfiguring deposit.

3. Observations on the egg-laying habits of the codling moth showed that very little oviposition took place before mid-June. The egg-laying of the first brood of moths was at its peak around June 22—26 and continued, at a lower level, until the end of July.

Acknowledgments.

The writers are indebted to C. P. Norbury, Esq., who provided all facilities for carrying out these trials in his plantation. They also wish to express their thanks to Dr. H. Martin, to whom the planning of the experiment is largely due.

REFERENCE.

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THE EFFECTS OF COPPER SPRAYS ON MARKETABLE YIELD AND STORAGE ROTS OF OUTDOOR TOMATOES.

By H. E. CROXALL.

Object of Experiment.

The field trial described below was carried out as a sequel to those reported previously (1). There were two main objects in planning this experiment. Firstly it was desired to make a further test of copper sebacate as a spray for controlling blight, *Phytophthora infestans*, since, in the 1943 trial, shortage of material had made it impossible to obtain a fair comparison between this substance and other copper sprays (1). The second object was to determine if spraying with a copper fungicide had any influence on the incidence of fruit rots caused by the fungus *Didymella Lycopersici*. This fungus has become of major importance on outdoor tomatoes in the South West in recent seasons. It attacks the stems, usually just above soil level, causing a canker, so that the plants wilt and often die. In some cases this disease may kill up to fifty per cent. of the plants. More often it is the attack on the fruit which is most serious. It causes a black rot starting at the calyx or from a wound on the surface of the fruit. Extremely heavy losses of outdoor tomatoes have occurred towards the end of the season especially in fruit ripened off the plant. The routine spraying against tomato blight appeared to have little effect in preventing infection of the fruit by *Didymella*. Dipping green fruits in fungicides and in oil emulsions containing fungicides in an attempt to protect the vulnerable calyx area gave little control. It seemed that infection had probably

taken place before the fruit was picked. A second observation was that the disease appeared in the field to some extent before the first blight preventive spraying was made. It was therefore decided to test whether earlier and more frequent spraying with a copper fungicide would give any protection against this disease. A subsidiary object was to see if this more intensive spraying caused injury to the plants.

Materials and Methods.

In order not to complicate the trial unduly, only two spray materials were used. These were copper sebacate and, as a comparison, a proprietary spray containing copper oxychloride. This spray was selected, as it is one popular with tomato growers and proved effective in the previous trials (1). The copper sebacate was made up with sulphite lye so that the fluid applied to the plants contained approximately the same amount of the wetter as did the proprietary mixture. Both sprays were diluted to contain 0·1% copper.

There were six treatments. Treatment 1 was the unsprayed control. Treatment 2 was the proprietary spray applied twelve times at weekly intervals beginning on July 12th. Treatment 3 was the same compound applied at six forthnightly intervals starting on July 19th. The same material was used in Treatment 4, but only three applications were made at intervals of four weeks, beginning on July 26th. Treatments 5 and 6 were copper sebacate applied at fortnightly and four weekly intervals respectively. Treatment 5 was applied on the same occasions as Treatment 3 and Treatment 6 on the same dates as Treatment 4. This spray programme is summarised in Table I.

TABLE I.

Dates of Spray Applications.

Treatment No.	July			August					September			
	12	19	26	2	9	16	23	30	6	13	20	27
1 ..	—	—	—	—	—	—	—	—	—	—	—	—
2 ..	C	C	C	C	C	C	C	C	C	C	C	C
3 ..	—	C	—	C	—	C	—	C	—	C	—	C
4 ..	—	—	C	—	—	—	C	—	—	—	C	—
5 ..	—	S	—	S	—	S	—	S	—	S	—	S
6 ..	—	—	S	—	—	—	S	—	—	—	S	—

C = Copper oxychloride.
S = Copper sebacate.

There were four replicates of each treatment arranged in randomised blocks. Two of the blocks received compost and the other two artificial fertilisers. Each small plot contained nine plants of each of the following varieties: Stonor's Prolific, Sunrise, E.S.1., Potentate, Market King and Ailsa Craig. The plants were 1′ 6″ apart in rows which were 3′ 6″ apart, so that each small plot was approximately 1/160 acre. Spraying was carried out with a barrow pump as described in a previous paper (1).

Results.

(1) *Yields.*

No information was obtained on the relative merits of the two spray

materials in controlling blight, as this disease did not appear in any plot throughout the season. The abnormally low incidence of this disease throughout the Western Province was probably due to low temperature.

There was no sign of any spray damage except a slight hardening of foliage on the plots sprayed weekly. Even on these plots growth was not less vigorous than on the unsprayed controls, nor was there any detectable deleterious effect on flower formation or setting.

No plants were killed by infection with *Didymella Lycopersici*, but stem lesions were found at the end of the season on two plants in control plots, one in the plots receiving weekly spraying and two each in all other treatments. Thus no useful information was obtained on the effect of copper spraying in controlling the stem canker phase of the disease.

In spite of the low incidence of stem infection a few ripe fruits were found to be infected in early August. Unfortunately it was not possible to record numbers of fruit infected in August and early September, but records were taken from mid-September onwards. From this date the incidence of fruit infection increased slightly on all plots but was most marked on the varieties Ailsa Craig and E.S.1. Crop weights of marketable fruit were recorded for each variety in each plot. These results are summarised in Table II.

TABLE II.

Weights in Tons per Acre of Ripe Fruit Picked.

Variety.	Un-sprayed Control.	Copper Oxychloride.			Copper Sebacate		S.E.	Difference required for significance	
		Weekly	Fort-nightly.	Four-weekly.	Fort-nightly.	Four-weekly.		5%pt.	1%pt.
Ailsa Craig ..	3·93	5·80*	5·48*	6·09*	5·77*	4·87	0·528	1·54	1·87
E.S.1 ..	4·75	7·30**	6·84**	6·35**	6·13**	6·06**	0·363	1·06	1·28
Market King ..	5·45	4·96	5·94	4·54	4·84	5·67	0·594	1·74	2·10
Potentate ..	7·79	7·85	8·28	8·00	9·29	7·40	0·754	2·21	2·66
Stonor's Prolific	4·92	6·15	4·86	4·57	5·06	5·54	0·544	1·59	1·93
Sunrise ..	5·19	5·40	5·50	6·23	6·84*	5·18	0·437	1·28	1·55
All varieties ..	5·34	6·25**	6·16*	5·97	6·32**	5·79	0·249	0·73	0·88

* Significantly greater than control at 5% pt.
** „ „ „ „ „ 1% pt.

It can be seen that in the two varieties Ailsa Craig and E.S.1, in which *Didymella* rots were most obvious, spraying resulted in a significant increase in the yield of marketable fruit. With E.S.1 all treatments gave a yield significantly greater at the 1% pt. than that of the control, while with Ailsa Craig all treatments except the four-weekly spraying with copper sebacate gave an increased yield significant at the 5% pt. As the only cause of crop loss observed was infection by *Didymella* and as the disease was most severe on these two varieties it seems possible that the increased yield from the sprayed plots was due to partial control of the disease by spraying. In only one other variety, Sunrise, was there any significant increase in yield due to treatment, and this was given by the fortnightly spraying with copper sebacate.

There was no significant difference between the yields from the blocks receiving compost and those receiving artificial fertilisers.

On September 22nd all green fruit remaining on the plots was picked and weighed. The total yields of green and ripe fruit for all treatments and varieties is shown in Table III.

TABLE III.

Weights in Tons per Acre of Total Fruit Picked.

Variety.	Unsprayed Control.	Copper Oxychloride.			Copper Sebacate.		S.E.	Difference required for significance.	
		Weekly	Fortnightly.	Fourweekly.	Fortnightly.	Fourweekly.		5%pt.	1%pt.
Ailsa Craig ..	11·43	15·30**	13·70	15·83**	15·10**	15·15**	0·827	2·42	2·92
E.S.1 ..	13·85	15·33	15·00	16·00	16·36	15·48	1·438	4·20	5·08
Market King ..	16·60	13·30	13·47	15·10	17·49	16·98	1·515	4·43	5·36
Potentate ..	15·00	13·17	14·84	14·74	14·25	16·78	1·218	3·56	4·31
Stonor's Prolific	11·89	12·47	11·57	12·55	14·57	13·09	1·148	3·35	4·06
Sunrise ..	14·88	12·91	15·48	15·74	13·92	16·24	1·385	4·05	5·21
All varieties ..	13·95	13·75	14·02	14·99	15·29**	15·62**	0·363	1·06	1·28

In only one variety, Ailsa Craig, was there a significant increase in yield due to spraying. This is not surprising when one considers that over half the crop was picked green and that no disease could be seen on the green fruit.

(2) *Storage Rots.*

The fruit of each variety from each plot was placed in separate fruit trays and left to ripen in a fruit store loft. The room was unheated and under these conditions of low and fluctuating temperatures ripening was slow. All the fruit was examined at fortnightly intervals, ripe fruit and fruits showing rots being removed and weighed. A random sample of infected fruit was examined on each occasion to determine the causes of rotting. Seventy-eight per cent. of the samples were infected with *Didymella*, fourteen per cent. with *Botrytis*, and two per cent. with *Mucor* and *Rhizopus* spp. In the remaining six per cent. only bacteria were found, but it is probable that frost damage had caused breakdown of the fruit, as this portion was confined almost entirely to the last inspection on November 28th, which was during a frosty period. As the weights of fruit differed in each tray the weight of sound marketable ripe fruit was expressed as a percentage of the weight of green fruit brought into the store. The results are given in Table IV.

There was no significant differences in the percentage of marketable fruits from the blocks receiving compost and those receiving inorganic fertilisers.

In all treatments losses were high, probably partly due to the storage conditions causing slow ripening and hence lengthening the period in which the fruit was exposed to infection. The conditions were favourable for development of rots and the proportion of infected fruit was successively larger at each examination. The frosts in November may have caused the fruit to become more susceptible to decay. There was, however, a significant response to spraying in all varieties except E.S.1 and Sunrise. In the other

four varieties the tomatoes which were sprayed weekly with copper oxychloride gave a higher percentage of sound fruit than the unsprayed controls. In two cases the difference was significant at the 1% point. With the varieties Market King and Stonor's Prolific fortnightly spraying with copper oxychloride and copper sebacate gave a significantly higher percentage of sound fruit. Responses also occurred with the fortnightly spraying of copper sebacate on Ailsa Craig and the four-weekly spraying of copper oxychloride on Ailsa Craig. The increase in percentage of marketable fruit from the sprayed plots of E.S.1 and Sunrise only just failed to be statistically significant. In these varieties the quantities of fruit varied considerably from tray to tray, and there were many very immature fruits which were extremely slow to ripen. When the total fruit of all varieties was considered all sprayed plots showed a significantly higher percentage of sound fruit than the unsprayed plots. With all treatments except the four-weekly spray with copper sebacate the difference was significant at the 1% point. The weekly spraying with copper oxychloride gave a significantly higher percentage of sound fruit than any other treatment. The difference between the fortnightly and four-weekly spraying with this material just failed to be significant, but with copper sebacate the fortnightly spraying gave a result just significantly better than the four-weekly spraying.

TABLE IV.

Percentage of Marketable Fruit Ripened in Store.

Variety.	Unsprayed Control.	Copper Oxychloride			Copper Sebacate.		S.E.	Difference required for significance	
		Weekly	Fortnightly.	Four-weekly.	Fortnightly.	Four-weekly.		5%pt.	1%pt.
Ailsa Craig ..	26·3	54·4**	38·0	33·8	41.0 *	34·9	4·74	14·30	19·77
E.S.1 ..	36·1	50·3	53·9	41·8	44·7	38·6	6·26	18·06	26·08
Market King ..	28·9	54·6*	47·3*	34·0	45·5*	32·0	4·42	13·30	18·39
Potentate ..	32·4	48·3*	42·2	44·7	45·0	46·4	4·75	14·32	19·80
Stonor's Prolific	23·2	40·7*	39·7*	44·1*	41·8*	36·0	5·12	15·43	21·34
Sunrise ..	35·0	55·4	46·7	38·6	51·0	33·8	7·11	21·41	29·62
All varieties ..	30·3	50·6**	44·6**	39·5**	44·8**	37·0*	1·86	5·61	7·76

* Significantly greater than control at 5% pt.
** " " " " " 1% pt.

Discussion.

Some explanation is necessary of this partial control of storage rots by field spraying and also of the differences in efficiency of the various treatments. In all treatments the last spraying was given shortly before the final picking so that control of rots was not entirely due to covering the fruit with a copper compound at this stage, as all spray treatments should have given similar results. Previous trials of dipping the tomatoes in copper and other fungicides had also given negative results. It seems that in the current experiment the difference between the results of the treatments may be due to differences in the amount of infection during the growing season. Consequently the weekly spraying, by maintaining the highest level of fungicidal protection, was the most effective in preventing the infection of fruit in the field. The protection

was not complete, but it is suggested that the proportion of infected fruits was less on the trays from the plots which had been sprayed most intensively. Thus in these trays the chances of sound fruit being in contact with infected ones was less and the spread of the disease therefore slower in these trays.

The methods described above do not offer an economic solution for the control of *Didymella* and *Botrytis* rots. Nevertheless, some measures of control were obtained by early and weekly application with copper oxychloride and a less effective control with fortnightly spraying with either this substance or copper sebacate. It thus appears that the possibility of devising a spray programme for tomatoes which would protect the fruit in the field against *Didymella* infection is worth further investigation. More research is required in order to obtain sprays which give more adequate protection of the fruit, particularly around the calyx, and also upon the times at which applications of the spray should be made. As with blight, caused by *Phytophthora infestans*, it is probably essential that spraying should start before the disease appears.

Summary.

1. An account is given of a spraying trial on outdoor tomatoes using copper oxychloride at intervals of one, two and four weeks, and copper sebacate at intervals of two and four weeks.

2. No Blight occurred on any plot throughout the season.

3. No appreciable damage was caused by any treatment even with twelve weekly applications of copper oxychloride.

4. In the varieties Ailsa Craig and E.S.1 significantly higher yields were obtained from sprayed plots probably due to partial control of infection by *Didymella Lycopersici*.

5. In ripening of green fruit in store there were considerable losses due to infection by *Didymella* and to a lesser extent *Botrytis*.

6. The losses were significantly lower in fruit which had been sprayed. The greatest reduction in loss was in the fruit which had received twelve sprayings with copper oxychloride.

7. The possibility of controlling *Didymella* infection of the fruit by spraying is discussed.

Acknowledgment.

The writer is indebted to Dr. Kearns and his co-workers for much advice and assistance in carrying out the spraying.

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RIBOFLAVIN IN FRESH FRUITS.

By DILYS P. JAMES.

Very little information is available concerning the presence of riboflavin in fruits, particularly in those fruits most widely cultivated in the British Isles. In an attempt to remedy this, the riboflavin contents of gooseberries, strawberries, raspberries, loganberries, black currants, blackberries, plums, damsons, pears, apples and tomatoes have been assayed during the 1944 season.

EXPERIMENTAL.

Material and Methods.

All the fruits tested were mature and in good condition. With the exception of pears, apples and some samples of tomatoes (noted in the text),

extraction was begun within twenty-four hours of picking, the fruit being kept in the cold (36° F.) until required. The apples were stored at this temperature and samples taken between six and ten weeks after picking. The pears were picked when slightly immature and allowed to ripen at room temperature.

Riboflavin estimations were made by the method of microbiological assay published by Snell and Strong in 1939 (1) and later modified by Barton-Wright and Booth (2). The technique employed by Kodicek and Worden (3) was found convenient and was therefore adapted to meet the needs of this experiment. Details of the procedure used are given below.

Sampling.

Duplicate samples were taken from each batch of fruit. The total number of samples of each fruit examined is given in Table II.

Soft fruits were hulled and the whole fruits weighed in representative samples. Stone fruits were wiped in a dry cloth and at least three representative fruits selected for each sample. Before weighing, stems and stones were removed with the minimum loss of flesh and juice. Hard fruits were also wiped, gooseberries being first "topped and tailed" and then sampled as for soft fruits. The stems of apples and pears were removed and three fruits of average size divided into eighths from calyx to stalk. Two diametrically opposite portions were taken from each fruit and bulked to form one sample. Tomatoes were sampled in a similar manner.

Where samples of peel only were required the fruits were peeled very thinly with a scalpel and any adhering flesh removed by scraping. "Core" samples were also freed as far as possible from flesh.

Extraction of Riboflavin.

The weighed samples were ground finely with sand, and autoclaved with 50 ml. of normal hydrochloric acid, for 15 minutes at 15 lbs. pressure. The deposit was removed by squeezing through double muslin which had been previously rinsed with acid. After adjusting the pH to 6·8 against bromothymol blue, with ammonium hydroxide and acetic acid, the extract was made up to the required volume. All extracts were kept in the dark between operations and precautions were taken to protect them from light during manipulation.

Removal of Fat.

Certain lipoids and fatty acids have been proved to stimulate, and others to inhibit, the growth of *Lactobacillus helveticus* (4, 5, 6). Samples of fruit were therefore extracted for three hours with ether in a Soxhlet tube, before riboflavin determinations were made. No difference was found between these results and those obtained when the riboflavin extract was shaken with chloroform before being assayed, as recommended by Kodicek and Worden (3). The latter method was therefore adopted, the chloroform being separated off and suitable aliquots taken for assay from the aqueous layer. Soxhlet extraction was used for samples of peel and core.

Assay of Riboflavin.

The riboflavin content of each extract was assayed at three different levels, the middle level giving a total of 0·07 μg riboflavin per assay flask. Triplicate readings were made at each level, the extract being thus assayed nine times. The standard curve was obtained from a series of twenty-one flasks containing riboflavin at seven levels of concentration, ranging from 0 to 0·4 μg/10 ml. present in the flask.

It was found convenient to use 75 ml. conical flasks for all assays. These had the advanatge over test-tubes in that the final titration could be made directly in them. Each assay and standard flask contained 5 ml. basal medium, a suitable volume of the extract under test, or of riboflavin solution in the case of the standard flasks, and saline (0·9% NaCl solution), to bring the total volume in each flask up to 9·5 ml. The flasks were plugged with cotton wool and autoclaved for 15 minutes at 15 lbs. pressure.

The basal medium was similar to that used by Barton-Wright and Booth (2) with the following exceptions :—

Xylose was increased to 2 gm./litre of medium.
Pantothenic acid was increased to 100 μg./litre of medium.
Sodium acetate (anhydrous) was added 1·75 gm./litre of medium.
Nicotinic acid and asparagine were omitted.

The inoculum was prepared as recommended by Barton-Wright and Booth (2), 0·5 ml. of a saline suspension of the organism being added to each flask. The organism used was *Lactobacillus helveticus*, U.S.A. strain 7469. All flasks were incubated at 37° C for 72 hours.

Observations on the effect of temperature differences during incubation, made during the work here, agree with those of Price and Graves (9). The following are examples of titration readings given by a series of assay flasks incubated in duplicate on the upper and middle shelves of an incubator. The temperatures given are the average maximum temperatures of five positions on each shelf.

	ml. 0·2 *N* NaOH
Upper (36·8°C.)	1·9, 2·04, 2·34, 2·72, 3·7
Middle (36·2°C.)	1·6, 1·9, 2·06, 2·5, 3·5

These variations may not appear very great, but a difference of 0·2 ml. in the titration reading may be equivalent to a difference of 0·05 μg. riboflavin in the result, and this is of the highest importance when small quantities of riboflavin are being assayed.

Here the difficulty was overcome by using triplicate sets of flasks, so enabling them to be distributed evenly over three shelves of an incubator. The positions on each shelf were so arranged as to minimise differences in temperature from back to front of the incubator, though in the one used these were very slight. The average titration reading of the triplicates was used in calculating results.

The lactic acid produced during incubation was titrated against sodium hydroxide solution (0·1 *N*), in a microburette, using bromo-thymol blue as an external indicator. This was necessary owing to the dark colour of some of the extracts after autoclaving.

Some examples of weights of samples taken and quantities of extract used for assay, together with the readings obtained, are given in Table I.

TABLE I.

Fruit	Sample (gm.)	Vol. of extract (ml.)	Aliquot per assay flask (ml.)	Average titration (ml.)	μg. Riboflavin	
					/assay flask	/gm. fruit
Blackcurrant ..	50·10	250	0·75	3·8	0·092	0·57
Damson (stoned)	50·98	250	1·0	2·81	0·072	0·35
Strawberry ..	51·23	250	1·0	2·5	0·06	0·29
Apple (flesh) :	71·37	250	2·5	3·36	0·07	0·1

RESULTS.

TABLE II.

RIBOFLAVIN IN WHOLE FRUITS.

Fruit	Variety	No. of Samples	Riboflavin (μg./gm.)	
			Range	Average
Blackcurrant	Westwick Choice	4	0·55 — 0·61	0·58
Blackberry	(cultivated)	2	0·34, 0·38	0·36
*Damson	Shropshire Prune	2	0·32, 0·35	0·34
Raspberry	Lloyd George Norfolk Giant	6	0·31 — 0·38	0·34
Strawberry	Royal Sovereign	4	0·27 — 0·47	0·33
Pear	Bristol Cross Conference	6	0·28 — 0·36	0·33
Tomato	—	6	0·25 — 0·39	0·33
Loganberry	—	3	0·26 — 0·29	0·28
Gooseberry	Keepsake Leveller Whinham's Industry	6	0·24 — 0·27	0·26
Apple	Allington	7	0·14 — 0·36	0·23
*Plum	Victoria Giant Prune	4	0·18 — 0·27	0·22
Apple	Bramley	6	0·06 — 0·16	0·11

* The figures given are for the stoned fruit.

It will be seen from Table II that, of the fruits examined, black currants had the highest riboflavin content (0·58 μg./gm.) and culinary apples the lowest (0.11 μg./gm.).

TABLE III.

DISTRIBUTION OF RIBOFLAVIN IN FRUITS.

Fruit	μg./gm.			Approx. % total content		
	Peel	Core*	Flesh	Peel	Core*	Flesh
Pear (Conference) ..	1·12	0·82	0·25	15	6	79
Apple (Allington) ..	0·77	0·78	0·12	20	16	64
Apple (Bramley) ..	0·61	0·46	0·061	27	19	54
Tomato	0·83	0·67	0·30	15	20	65

* " Core " represents calyx, placenta and seeds of apples and pear, and endocarp and seeds of tomato ; the tomato placenta is included in " Flesh."

The distribution of riboflavin in pears, apples and tomatoes was investigated and it was found that, weight for weight, both peel and core contained more riboflavin than the flesh. When the fresh weight ration of

peel/core/flesh was taken into consideration, the flesh was seen to contain roughly one-half to three-quarters of the total riboflavin of the fruit (Table III). The figures for tomatoes given here were obtained on fruit ripened indoors and are higher than would have been expected from those in Table II, which were given by fruit picked when ripe and assayed when fresh.

DISCUSSION.

All the fruits examined here and those for which figures are available elsewhere (7, 8) are low in riboflavin, especially when compared with other sources such as yeast extract, liver and whole-meal bread. The daily adult intake of approximately 2 mg. is represented by 8 lbs. of black currants or 13 lbs. of tomatoes.

Varietal differences in riboflavin content appear to be very slight, from the limited number of varieties of each fruit tested, three varieties of gooseberry giving a range of but 0·24—0·27 μg. riboflavin/gm. A wider range is shown by different samples of a single variety of apple, but this is probably due to differences in size of the fruits sampled and the corresponding variation in peel/core/flesh ratio.

One sample of tomatoes which had been ripened indoors contained 0·67 μg./gm. Two samples of gooseberries which were kept in the cold (36° F.) for ten days, were found to contain 0·5 and 0·56 μg./gm. When examined the gooseberries were red but in good condition and free of yeast and mould. They were wiped thoroughly before being assayed. It is possible that part of the apparent increase in riboflavin content may be due to some loss of water by evaporation; the fruit was not weighed before being placed in the cold store. The difference would appear to be too great to be entirely accounted for in this way, and may warrant further investigation. The riboflavin contents of these samples are not included in the figures given in Table II.

The microbiological method of assay was adopted in preference to the fluorometric method owing to the difficulties presented by the latter. Two major difficulties of this method are (1), the presence of colloidal matter and/or fine suspended particles in the final solution to be assessed for fluorescence, and (2), the difficulty of measuring accurately small fluorescences given by solutions from products low in riboflavin (Barton-Wright and Booth (2)). These would have been emphasised when working with fruits. With the modifications already mentioned, the microbiological method has given consistent results and proved satisfactorily simple to carry out.

SUMMARY.

1. The microbiological method of assaying riboflavin has been adapted for use with fruits.

2. The riboflavin contents of eleven fruits widely grown in the British Isles have been found.

3. The distribution of riboflavin between peel, core and flesh of apples, pears and tomatoes has been determined.

4. The importance of obviating temperature differences during incubation, when small amounts of riboflavin are being assayed, has been emphasised.

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FACTORS INFLUENCING THE VITAMIN C CONTENT OF TOMATOES.

By A. POLLARD, MARGARET E. KIESER & JOAN D. BRYAN.

During the 1944 season a spraying trial of tomato varieties provided material suitable for a study of some of the factors influencing the nutritional quality of the fruit. As indicated in the preceding paper (1) ascorbic acid (vitamin C) was considered to be one of the main nutritional constituents of the fruit, and attention was therefore mainly directed to factors influencing the level of this compound. Some analyses of sugar, acid and total solids have also been made and will be described.

The factors which have been considered with regard to their influence on the composition of the tomatoes were the following :—

(1) Differences between individual plants.
(2) Differences due to truss position.
(3) Greenhouse treatment as compared with growth in the open air.
(4) The application of organic compost to the soil.
(5) The effect of variety, as between Market King and Ailsa Craig.
(6) The effect of ripening on or off the plant.

It was originally intended to obtain a full record of the fruit from all trusses from a given number of plants, but as a result of the exceptionally cold and sunless summer the fruit from the out-door plants ripened very poorly and even the later trusses on plants in the house failed to ripen before the onset of night frosts. The data for the upper trusses on many plants were therefore incomplete. It has, however, been possible to draw some general conclusions from the figures which have been obtained and these will be described.

Material.

Plants of the variety Market King were raised in a greenhouse and planted out in the open at the beginning of June in ground which had received a fertiliser dressing consisting of 3 cwt. meat and bone and 2 cwt. muriate of potash per acre. To one half of the ground an addition of organic compost was made at the rate of 10 tons per acre. Another set of the same batch of plants was put out on the same day in two adjacent lean-to cold houses. As before, one-half of each house received complete fertiliser at the above rate, while the other received organic compost in addition. All plants were stopped at the fourth truss and standard spraying procedure was applied throughout.

The variety Ailsa Craig was grown at the same time in large pots in normal potting soil, and half of the plants were housed in a cool greenhouse, while the others were placed outside the house in an unshaded position.

Picking commenced at the end of August in the houses and in the first week in September in the open. As a result of the weather prevailing at the time it became necessary to harvest the plants of Market King growing in the field at the beginning of October and they were then hung up complete with roots in the light in a cool greenhouse for the remaining fruit to ripen. Picking of the fruit in the cold houses continued until the first week in December.

The different treatments are summarised in Table I :—

TABLE I.

A	1—6	Market King	Greenhouse	N.P.K.
B	1—6	,, ,,	,,	,, + Compost
E	1—6	,, ,,	Outdoor	,,
F	1—6	,, ,,	,,	,, ,,
C	1—10	Ailsa Craig	Greenhouse	,,
D	1—10	,, ,,	Outdoor	,,

The analyses for ascorbic acid, sugar, titratable acid, pH and dry weight were carried out as described in the previous paper, taking as before several fruits from each truss as a combined sample whenever possible. The analyses of the fruit for these constituents will be described in turn.

Results.

Ascorbic Acid.

The figures for ascorbic acid in the tomatoes receiving the different treatments are set out in Table II. The figures were originally separated according to the date on which the fruit was picked, as it was considered probable that this would have an effect on its composition. The interval between September 1st and December 12th was accordingly divided into four equal periods and the analyses were grouped accordingly. Using the $\times^2$ test on pairs in which time of picking was the only variable, *i.e.* in which plant, truss and variety were similar, it was found that the period of picking produced no significant difference in the ascorbic acid content of the fruit. The results were consequently pooled for the subsequent analysis of variance.

The effect of allowing fruit to ripen on the plant as against ripening off the plant was then tested by an analysis of variance, using pairs of values in which fruit from the same truss was allowed to ripen under both conditions and within the same period. The average values for ascorbic acid in fruit ripened on or off the plant were respectively 23·10 and 18·06 mg./100 g. fresh weight, values which did not differ by more than the Significant Difference of 6·135. In this experiment, therefore, no difference between values for fruit ripened on or off the plant has emerged.

The variations remaining to be examined were therefore those due to

(*a*) Differences between plants of the same variety.
(*b*) Differences due to position of truss.
(*c*) Indoor and outdoor treatment.
(*d*) The addition of organic compost.
(*e*) Variety.

TABLE II.

ASCORBIC ACID IN TOMATOES. mg./100 g. fresh weight.

Plants	A				B				C				D				E				F			
Truss	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Pot No.																								
1	16	22	28		20	24		18·5	29	28	45	43	42				41	27	31	(23)	22	25	25	(18)
	15·5		20		22	25	25	(19)	32	33							(47)	(33)				(21)	(11)	(11)
			(18·5)		17	(20)	15																(12)	
					19																			
2	15·5				18	23	20	(18)	29	24	32	31	39					(36)	(43)	(38)	27·5	(49)	(29)	
	15				15	20	(17)		36	27		44	39						(38)		(22)	(25)	(27)	(46)
					16	30			33			29							(37)				(22)	(29)
						18																		
3	19	13	19	22	28	21	22	(15)	23	33		39									(22)	(21)	(33)	(35)
		17		27	18	20	(16)		35			(28)										(23)		(37)
				(17)	17							35												
					16·5							(30)												
4	19	17·5	25	28	20	21	19	25	28	23	32	41	50	35·5	30		33·5	39	(46)			(28)		
	13	25	23			22	20				35·5	39	40		27·5			31	(39)					
	16												29											
5					29				21								(44)	40	34		29	35		
																		(24)	(21)			(28)		
6	23	16	21·5	29		16	(14)	(19)					30·5	34			(25)				38	(37·5)		(30)
	15	17	18	(17)		(14)	(15)														(22·5)	(24)		
			(10)	14																				
				20																				
7									20	17	24	31		31	29									
									28	23		37		36										
									31															
8									18	24	23	21	27											
									25		24	(23)												
											20	(19)												
												28												
												24												
9										21			35											
													37											
10									27	37·5			33·5	30	36									
									37				41·5	31	39									
														32										

(Values in brackets are for fruit ripened after harvesting).

Inspection of Table II reveals large differences in the ascorbic acid production in fruit grown under glass and out of doors (*e.g.* A and B against E and F). A direct analysis of variance is therefore unreliable if the mean value for any of the above factors is biassed by an excessive proportion of results from outdoor plants; *e.g.* plants numbered 5, of which only one value from Market King grown under glass was obtained against eight from Market King grown outdoors. Variation within plants was accordingly grouped with that attributed to error.

The effects of factors (*b*), (*c*) and (*d*) were examined by an analysis of variance of treatments A, B, E and F which is shown in Table III.

TABLE III.

	Degrees of Freedom	Sum of squares of deviations	σ^2
Truss	3	89·675	29·892
Indoor v. outdoor	1	3698·505	3698·505
Compost v. no compost	1	204·805	204·805
Remainder	124	5520·440	44·5197
Total	129	9513·425	

From this the following conclusions may be drawn with regard to the headings given above.

(*b*). The differences in ascorbic acid content due to position of truss are insignificant.

(*c*). The average ascorbic acid content of tomatoes grown in the open was 30·28 mg./100 g., while the corresponding figure for those grown under glass was 19·45 mg. As the difference required for significance (P = 0·05) is 2·35, it is evident that growing the plants out of doors has given a greater production of ascorbic acid.

(*d*). The average ascorbic acid content of fruit from plants receiving compost was 22·86 mg., that of fruit from plants grown without the addition was 25·39 mg. As the difference required for significance is 2·34, this suggests that the addition of compost has decreased ascorbic acid production. Bias due to a greater preponderance of outdoor grown fruit would favour plants receiving compost, for these estimations included 32 from outdoor and 42 from indoor grown plants, whereas the estimations from plants receiving no compost are 22 from outdoor and 34 from indoor grown plants. In this trial it may therefore be concluded that the use of compost has given fruit with a lower ascorbic acid content.

(*e*). The effect of variety was determined by an analysis of variance of results from treatments A, C, D and E which is given in Table IV, all variance due to plant and truss being taken as contributing to error.

Varietal differences are shown to be in favour of Ailsa Craig, which gave a mean value of 30·98 against one of 25·39 for Market King (significant difference 2·44).

The greater production of ascorbic acid in outdoor grown fruit is again shown in these treatments, as the mean value for outdoor fruit is 34·89 against one of 25·25 for fruit grown under glass, with a significant difference of 2·51.

TABLE IV.

	Degrees of Freedom	Sum of squares of deviations	σ^2
Variety	1	1006·58	1006·58
Indoor v. outdoor	1	2785·82	2785·82
Remainder	129	6228·76	48·285
Total	131	10021·16	

A differential response between the two varieties in ascorbic acid production in plants grown out of doors as compared with those grown under glass is revealed by an analysis of variance of the mean values (Table V).

TABLE V.

	Market King	Ailsa Craig	
Indoor	19·16	29·23	48·39
Outdoor	35·02	34·77	69·79
	54·18	64·00	118·18

	Degrees of Freedom	σ^2
Variety	1	24·1081
Indoor v. outdoor	1	114·4900
Interaction	1	26·6256
		165·2237

Variance attributed to interaction is greater than that ascribable to variety ; a result which suggests that differences between ascorbic acid production in outdoor grown fruit and in fruit grown under glass are more marked in Market King than in Ailsa Craig.

It should be pointed out that the differences in ascorbic acid content of fruit grown under glass and in the open are not to be attributed to differences in water content between the two sets, for when calculated on a basis of the average dry weight, the ascorbic acid figures show even greater differences in the same direction than when calculated on a basis of fresh weight.

Other Constituents.

As the data for sugar, titratable acid and dry matter were found to be too incomplete for statistical treatment, only the general trends shown by the results will be indicated. The average values for these constituents and for the different treatments are shown in Table VI, where the values for fruit ripened on the plant and for fruit ripened off the plant are shown separately, the latter being in brackets.

TABLE VI.

Treatment	Sugar as invert % Fresh Weight	Titratable acid, ml. N/10 per 100 g. Fresh Weight	Dry Matter % Fresh Weight
A	3·60 (3·60)	53·4 (44·1)	7·2
B	3·65 (3·28)	64·9 (51·2)	6·7 (7·5)
C	3·93 (4·38)	44·8 (46·0)	7·1 (8·2)
D	3·23	36·4	7·1
E	2·75 (2·56)	36·5 (44·9)	5·7 (6·2)
F	2·25 (2·30)	44·9 (45·8)	5·6 (6·2)

The level of sugar in both varieties was higher in the fruit from the greenhouse grown plants (A, B and C) than in those from plants grown in the open (D, E and F). A strict comparison is not possible, however, since most of the estimations for Market King grown out of doors were obtained from fruit ripened after picking. In a series of tests where part of a given truss was ripened on the plant and part ripened off the plant at the same time, it was found that the percentage of sugar in the fruit was slightly lower in those ripened off the plant. As the later fruit from the truss ripened the relative proportion of sugar increased in those ripened off the plant, but at the same time the moisture content fell as a result of evaporation, and this masked an actual fall in sugar. No marked differences were seen between the sugar contents of the batches of fruit grown with and without the addition of compost, either in the greenhouse (A, B) or in the open (E, F).

The average amounts of titratable acid present followed those for sugar in their general trend, but the fruit showed greater variations within treatments. This was no doubt to be ascribed to slight variations in the degree of ripeness as indicated in the earlier paper in this Report.

The figures for dry matter in the variety Market King showed a considerable difference between the fruit from plants grown under glass as compared with that from those grown in the open. The fruit ripening on the plants under glass had a higher content of dry matter than the fruit ripening on plants in the open (A, B and E, F), and the figures for fruit ripening after picking still showed the same difference between the two sets of plants, although fruit ripening after picking had a higher dry weight than the corresponding fruit ripening on the plant in each case.

Discussion.

The composition of the tomato has, for some time, been known to be influenced by a considerable number of factors such as individual variations within a given variety, the actual variety itself and the climatic conditions. The variation is well shown by the ascorbic acid content, with which this paper if primarily concerned, and it has been found that the level of this compound is more influenced by the factors listed above than by nutritional treatments

to which the plant has been subjected. Lyon and co-workers (2), for example, have found that the level of major and minor elements, although influencing the growth and fruitfulness of the plant, produced little change in the ascorbic acid content of the fruit except in iron deficient plants which had a higher ascorbic acid content. Considerable variations in ascorbic acid have been noted in the fruit from a given plant (Kidson 3). The variation between plants may indeed be greater than that between the average values for different varieties (Hallsworth and Lewis 4); the average values do, nevertheless, show definite differences between varieties grown under the same cultural conditions. A relation has also been found between ascorbic acid content and size of fruit, small fruit having a higher content than large fruit. The difference has been considered due in part to the greater proportion of skin with a higher ascorbic acid content in the small fruit (Wokes 5, Kidson l.c.) and also to the greater degree of exposure to light per unit weight in the small fruit (4). The effect of sunlight in increasing ascorbic acid content has been reported by the above workers and also by Kaski, Webster and Kirch (6), who found an increase after periods of sunshine and an adverse effect caused by rainfall.

In the analysis of the results, variations between plants were included with those ascribable to error and the differences between fruit from individual trusses on the same plant were found to be not significant. Furthermore, no significant difference in composition was found when fruit from the same truss on a given plant was picked at different times between the first week in September and the first week in December. It is possible that weather differences were not sufficiently marked to produce a noticeable effect, for after the first half of September the weather showed no great variation.

Differences in the length of day also appeared to produce no significant effect on the composition of fruit picked over this period. In the earlier experiment carried out with Market King in the greenhouse in May and June (1), the later trusses had a higher ascorbic acid content than the earlier and lower trusses. The difference was, however, ascribed in the main to differences in illumination due to site. The length of day appears, nevertheless, to have had an effect on the general level of ascorbic acid in the two experiments, for in the earlier trial when the period of daylight was from 15 to 16 hours, the fruit had an average ascorbic acid content which was much higher than that of the fruit of the same variety from the greenhouse in September—December. The former was, indeed, as rich in ascorbic acid as the outdoor fruit ripening during the later period when the daylight decreased from 13 down to 8 hours.

The effects of differences in light intensity and in temperature are probably responsible for the considerable difference found in this trial between the composition of fruit grown in the greenhouse and that grown in the open. Sugar and dry matter were higher in the former, but ascorbic acid was significantly lower. For Market King the average ascorbic acid content of fruit grown under glass was only $\frac{2}{3}$ of that of the fruit grown in the open. A similar result was found by Currence (7) and by Brown and Moser (8), although the workers at Ithaca (2) found no significant difference in their trials.

The only variation made in manurial treatment in this experiment was in the addition of organic compost to the soil before planting. The effect on yield and on the incidence of disease is described elsewhere in this Report (9). No effect was observed on the proportion of sugar or total solids in the fruit, but the ascorbic acid content of fruit from the plots receiving compost was slightly lower than that of the controls. The effect was not due to differences in the dry weight arising from differences in the proportion of fruit ripened

after picking in the two sets, for calculation on a basis of dry weight gave an even greater difference in the same direction.

The two varieties of tomato used in this trial show distinct differences in ascorbic acid production, the fruit from Ailsa Craig giving higher values than that from Market King. The former variety also showed less variation in ascorbic acid, sugar and total solids between fruit grown under glass and that grown in the open. The greater variation in Market King may be a result of a greater difference in site between the two sets of plants of this variety, for the outdoor plants were grown in a more exposed position and on higher ground than the outdoor plants of Ailsa Craig.

In view of the necessity for ripening a considerable proportion of the outdoor tomato crop artificially in adverse seasons, it is of interest to note that fruit ripened after picking appears little inferior nutritionally to that ripened on the plant in the normal manner. Brown and Moser (l.c.) found no significant loss of ascorbic acid in fruit allowed to stand at room termperature for 18 days, and Wokes (l.c.) has reported that fruit picked and ripened in the light had an ascorbic acid content equal to that of fruit ripened on the plant ; ripening in the dark, on the other hand, gave fruit with a lower ascorbic acid content. In the present experiment no significant difference was found between fruit ripening normally and fruit ripening in the light after picking. Although in the latter there was some loss of sugar and of water and the fruit was lacking in fresh flavour, in so far as the chemical analyses show, the fruit was still of excellent food value.

The results which have been described indicate, therefore, that there is considerable variation in the ascorbic acid content of a given variety of tomato. The general level is affected by the location of the plants, *i.e.* whether they are grown under glass or in the open, the latter having a higher ascorbic acid content than the former. The conditions of growth appear to fix the level and to exert more effect than the conditions of ripening, for open air fruit ripened off under glass still shows the higher level of ascobic acid. The effect of variety is also important, different varieties showing different ascorbic acid levels under similar conditions of growth. The use of varieties with the higher ascorbic acid ranges would therefore ensure a crop with a higher food value than those with inherently lower ranges, even under adverse cultural conditions and seasons. It is proposed to carry out further trials on some of the tomato varieties commonly grown in this country and to compare their relative nutritional values.

Summary.

1. The ascorbic acid content of tomatoes varies from plant to plant within a variety, but in the autumn season no significant differences were found to be due to truss position.

2. Fruit grown in the open air had a higher ascorbic acid content than that grown under glass.

3. The application of organic compost gave fruit with a slightly lower ascorbic acid content, but no significant differences were observed in the other constituents.

4. Tomatoes ripened in the light after picking contained slightly less water and sugar than fruit ripened on the plant, but the ascorbic acid content remained unchanged.

5. Fruit of the variety Ailsa Craig had a higher ascorbic acid content than fruit of Market King, both in the open air and under greenhouse conditions.

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THE NUTRITIONAL VALUE OF PARTHENOCARPIC TOMATOES.

By A. POLLARD, MARGARET E. KIESER & JOAN STEEDMAN.

The induction of parthenocarpic tomatoes by the use of chemical agents is described by Swarbrick (1) in this Report.

A preliminary study has been made of some of the nutritional constituents of these tomatoes and the amounts present have been compared with those found in fruit produced by normal pollination at the same time and under identical greenhouse conditions. As the chief nutritional value of the tomato lies in its vitamin content rather than in its content of such substances as sugar, starch or acid, attention has been focussed mainly on the amounts of ascorbic acid (Vitamin C) present in the fruit. Some analyses of the other constituents have been made and the results will be described.

Methods.

Sampling. Fruits from individual plants and trusses were kept separate and where possible several fruits of average size were taken from a truss to give a combined sample. The determination of ascorbic acid, titratable acid, sugar and moisture were carried out on quarters cut longitudinally from each fruit and the quarters from several fruits were bulked to give representative samples.

Ascorbic Acid. The sectors were weighed in 5% meta-phosphoric acid solution immediately after cutting and then minced to a fine suspension in a simple disintegrator devised from a milk-shake mixer. A comparison was made between this method of disintegrating the fruit and the usual method of grinding with sand, taking duplicate samples from several fruits. It was found that the mechanical disintegration gave no loss of ascorbic acid due to the increased aeration, in fact this method gave values which were consistently slightly higher than those obtained by grinding. The suspension of pulp was made up to volume with 5% meta-phosphoric acid, mixed, coarsely filtered and titrated with dichlorophenol-indophenol in the usual manner.

The estimation of ascorbic acid by Mapson's method (2) using differential titrations with formaldehyde showed that interfering reducing substances were absent; the direct method of titration was therefore assumed to be reliable. The absence of interfering substances or of dehydro-ascorbic acid in tomatoes has also been reported by other workers (3).

Sugar and Acid. The samples for sugar and acid determination were minced in distilled water, filtered, and aliquots taken for the two estimations. Sugars were determined by the Shaeffer-Somogyi method after preliminary precipitation with lead acetate and were determined both before and after inversion. Titratable acid was determined by titration with N/10 NaOH using an external indicator and the results were expressed as ml. N/10 acid per 100g. fresh tissue.

pH. The pH of each sample of fruit was measured by the glass electrode, taking as before a quarter from each fruit and pulping the combined sample with a glass rod until homogeneous.

Dry Matter. The moisture content was determined by drying at 65°C. for 24 hours, as no vacuum oven suitable for routine work was available. Drying under these conditions gave, however, fairly good agreement with drying *in vacuo* at 60°C. to constant weight.

Results.

TABLE I.

Ascorbic Acid Content of Normal Tomatoes.

(as mg./100 g. fresh weight).

Plant No.	1	2	3	4	Average.
Truss No.					
1	17·2	26·3	16·3	19·1	
	20·8	20·7	15·7	20·9	
	18·6	19·1	16·0	20·1	
	—	24·6	17·7	—	19·51
2	22·5	28·2	24·6	20·5	
	18·4	22·7	19·2	22·1	
	—	26·1	20·1	28·7	
	—	—	26·2	—	23·24
3	22·4	28·3	27·7	29·4	
	—	19·8	—	27·4	
	—	29·7	—	—	26·39
4	32·8	30·5	39·8	38·4	
	—	—	—	34·8	35·26

The ascorbic acid values for the normal fruit are shown in Table I, in which the individual estimations are given for the different plants and truss positions, trusses being numbered 1 to 4 up the plant. Where possible several estimations were carried out on each truss. The corresponding values for the parthenocarpic fruit are shown in Table II, but in this case it was not possible to carry out determinations on all the truss positions. These results were therefore too incomplete for adequate statistical treatment, and it was necessary to make the assumption that the conclusions drawn from an analysis of variance of the normal fruit data could be applied to the data for the parthenocarpic fruit.

The statistical analysis for the normal fruit is summarised in Table III, and shows that there is a significant difference between the ascorbic acid values found for the different plants but that much greater variation is due to differences in truss position on the plant. As shown in Table I, the average values for the fruit from each truss show a significant increase in ascorbic acid content on passing up the plant from the bottom to the top truss. Fruit

from the top trusses contained on the average almost twice as much ascorbic acid as those from the lowest trusses.

TABLE II.

Ascorbic Acid Content of Parthenocarpic Tomatoes.
(as mg./100 g. fresh weight).

Treatment	β-naphthoxy-acetic acid			2:4-dichlorphenoxy-acetic acid		2:6-dichlorphenoxy-acetic acid	
Concentration (in p.p.m.)	10	10	100	10	100	10	100
Plant No.	5	6	7	8	9	10	11
Truss No.							
1	23·8	17·5	18·3	24·1	11·3	18·5	13·5
	—	18·0	17·5	30·4	12·8	22·8	11·5
	—	—	18·1	19·0	16·3	—	—
		(17·8)	(18·0)	(24·8)	(13·5)	(20·7)	(12·5)
2	28·2	26·6	—	—	—	24·6	—
		26·4		—	—	—	—
		23·3		—	—	—	—
		(25·4)		—	—	—	—
3	21·1	28·5	—	23·2	28·0	36·3	27·9
	—	—	—	29·4	—	—	—
				(26·3)			
4	—	—	—	27·7	41·4	—	33·9
	—	—	—	—	25·6	—	26·7
	—	—	—	—	37·8	—	—
	—	—	—	—	25·6	—	—
					(32·6)		(30·3)

Average values for trusses are given in brackets.

TABLE III.

	Degrees Freedom	Sum (Deviations)^2	Variance
Plant	3	112·11	37·57
Truss	3	963·92	321·31
Remainder ..	32	289·97	9·06
Total	38	1366·00	

The values for the parthenocarpic fruit also show the same general increase in ascorbic acid on passing to the higher positions on the plant. Assuming that the analysis of variance made for the normal fruit is applicable to the figures derived from the treated plants, the only noticeable effect of hormone treatment has been to depress slightly the ascorbic acid in the fruit from the plants receiving the 2:4 dichlor-phenoxyacetic acid and 2:6 dichlorphenoxy-acetic acid treatments at the higher levels of application (viz. 100 p.p.m.) In these fruits the ascorbic acid content is lower than would be anticipated, *e.g.* for Truss 1 of Plant 9 the three results give a mean value of 13·5 mg., which

differs from the mean value of 19·51 mg. for the normal plants by more than the significant difference of 3·90 calculated for 3 results. Similarly Truss 1 of Plant 11 gives fruit with an average ascorbic acid content of 12·5 mg., and this is lower than the value for the normal plants (19·51 mg.) by more than the significant difference of 4·65 as calculated for 2 results. The parthenocarpic fruit otherwise show no significant difference in ascorbic acid content from those produced normally.

Sugar.

The amount of sugar in the normal seeded fruit was found to vary over a considerable range, due in all probability to slight differences in the degree of ripeness, although as far as possible the fruit for analysis was chosen at a uniform firm ripe stage. The sugar appeared to be in form of reducing sugar and no appreciable amounts of sucrose were found. The values for both the normal and the parthenocarpic fruit are shown in Table IV, where it is seen that the latter fruit gave both a higher range of sugar contents and a higher average value than did the normal fruit. The difference is seen to be significant and it may therefore be concluded that the parthenocarpic fruit tended to contain more sugar than the normal fruit.

Acid and pH.

The titratable acid in both normal and seedless fruit showed great variations as shown in Table IV. The average values for the two sets were not, however, significantly different. The pH values likewise showed considerable variation. Taking the results as a whole the pH values for the normal fruit appeared slightly more acid than those for the parthenocarpic fruit, but the differences were not marked.

Dry Matter.

The proportion of dry matter in the fruit varied according to the amounts of acid and sugar present (Table IV); the mean values, however, showed no significant difference between the two sets of estimations.

TABLE IV.

	Normal Fruit	Parthenocarpic Fruit
Dry Matter (g./100 g. fresh wt.)		
Range	5·0 — 7·8	4·9 — 8·2
Average	6·49 ± 0·11	6·52 ± 0·13
No. of estimations	38	35
Significant Difference	0·34	
Sugar (g./100 g. fresh wt.)		
Range	2·46 — 5·50	2·86 — 6·44
Average	3·49 ± 0·08	4·01 ± 0·12
No. of estimations	38	35
Significant Difference	0·30	
Acid (ml. N/10 per 100 g. fresh wt.)		
Range	23·4 — 68·3	33·9 — 63·1
Average	49·80 ± 1·63	47·73 ± 1·21
No. of estimations	38	35
Significant Difference	4·14	
pH.		
Range	4·00 — 4·36	4·03 — 4·40

Discussion.

The results which have been described show that the normal and parthenocarpic fruit differ but little in their content of ascorbic acid, sugar and titratable acid. The seedless fruit have a slightly higher sugar content but show little difference in acidity or pH. The variations found in the amounts of these constituents in each type of fruit are no doubt to be ascribed to slight differences in the degree of ripeness. Sando, for example (4), has noted an increase in sugars and a decrease in acids during the process of ripening, although the water content of the fruit showed little change. Ascorbic acid on the other hand has been found to change but little during ripening, both in experiments carried out here and also by other workers (Wokes and Organ, 5): differences in ascorbic acid content cannot therefore be ascribed to variations in ripeness.

The fruit from the treated plants had a rather insipid flavour when compared with the normal fruit, and this would be expected as a result of differences in the sugar-acid balance and in the ratio of flesh to juice. Howlett (6) for example reported that parthenocarpic fruits were less acid and more mealy than the normal seeded fruits. The present results are in agreement with those of Janes (7) who found, on working with tomatoes induced by the action of indoleacetic and indolebutyric acids, that the sugar and starch contents of the seedless fruit were higher than those of the normal fruit and that the proportion of locular region was smaller in the former. The juice from the locules was also sweeter and less acid than the corresponding juice from the normal tomatoes. This author suggests that an accumulation of carbohydrates takes place in the seedless fruit which, in the normal fruit, would be utilised during seed formation. The differences in carbohydrate and acid in the present experiment are smaller than those described by Janes and may be due to some extent to the use of different chemical agents for inducing parthenocarpy. Mitchell and Whitehead (8), using β-napthoxy acetic acid, one of the compounds used in the present trial, also found no significant differences in size, fresh weight or total solids between the seedless and normal tomatoes. But they also found no differences in ascorbic acid content or in flavour, whereas in the present experiment a significant difference in ascorbic acid content was found in the lowest trusses of plants treated with the higher concentrations of 2:4-and 2:6-dichlorphenoxy acetic acids. In these the ascorbic acid values were lower than in the normal plants, but the differences were not large.

The variation in ascorbic acid between tomatoes from the lower and upper trusses in both normal and treated plants is at variance with results which have been obtained later in the season and which will be described in a separate paper. The higher values found for the top trusses may, however, be due to the effect of light on the fruit or on the plant during the growing season in the early months of the year, for the top trusses ripened later than the lower ones and under increasing amounts of light during May and June. In addition, the lower trusses were partially shaded by the walls of the greenhouse. The effect of sunshine and of length of day has been noted by a number of workers, *e.g.* Kaski, Webster and Kirch (3) and Hamner, Lyon and Hamner (9). The effect of climate and environment appears, indeed, to give rise to considerably greater variations in the ascorbic acid content of tomatoes than does the effect of parthenocarpic development.

Summary.

1. The ascorbic acid, sugar and acid contents of normal and of partheno-

carpic tomatoes have been compared. The methods of sampling and of analysis are described.

2. The ascorbic acid level was found to vary from plant to plant within each treatment, but a greater variation was found between trusses on a given plant.

3. The only significant difference between the ascorbic acid contents of the normal and the parthenocarpic fruit was found in the fruit from plants treated with the higher concentrations of chemical agents ; in this the ascorbic acid was lower than in the normal fruit.

4. The parthenocarpic fruit had a sweeter flavour than the normal fruit and contained slightly more sugar ; no significant differences in titratable acid or in total solids were observed.

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FACTORS AFFECTING QUALITY IN POTATOES.

By A. POLLARD, MARGARET E. KIESER, ALICE CRANG & T. WALLACE.

In a previous paper on the blackening of cooked potatoes (1) results were reported in which blackening after boiling occurred in potatoes grown on manurial plots at Long Ashton where potash and phosphate respectively were deficient, and in sand cultures where phosphate or calcium was omitted from the complete nutrient solution. These experiments suggested the examination of further samples from soils known to be deficient in potash, phosphate or lime.

During 1944 samples have been obtained from several field experiments on widely differing soil types, where outstanding deficiencies in the above three constituents have occurred and a wide range of fertiliser treatments have been tested. In addition, field and pot experiments have been carried out at Long Ashton to test manurial treatments, differential planting and harvesting times, and varietal differences.

The quality tests have been carried out on samples after boiling, the data obtained referring to external appearance, texture or flesh consistency, flavour and blackening.

In discussing the results the main emphasis is placed on blackening since special attention has been given to this factor in view of its great practical importance at the present time.

A point requiring special mention which has emerged from the tests is that where severe blackening has occurred naturally on poor soils no substantial improvement has resulted from any manurial treatment given, including potash and phosphate treatments and liming at rates exceeding those possible in farm practice.

On the other hand, varieties have shown wide differences in susceptibility to blackening and it is obvious that much can be done to alleviate the blackening problem by the use of resistant sorts. The results raise the issue of the advisability of using certain varieties of potatoes susceptible to blackening on particular soils if severe blackening is to be a deciding factor.

METHODS.

Collection of Samples.

The samples used were generally of ware size, taken at random from the produce of the various experimental plots. Each sample weighed 7 lb. or less, and with one exception, where paper bags were used, the samples were packed in small jute bags for transport to Long Ashton. The samples were brought to Long Ashton by road so as to avoid delays and were stored in bags in a cool building until immediately prior to testing.

Procedure of Testing.

The tests were carried our during the period 25.10.44—8.12.44, the procedure being as follows :—

Preparation of Samples. The samples were taken from store and 2 lb. of average size tubers collected, damaged or diseased specimens being discarded. In the later tests, the densities of the tubers were taken by immersing them in salt solutions of known specific gravity. The cooking sample was then drawn from those of average density. This procedure was found to give a more homogeneous sample.

Boiling Technique. Immediately before cooking, the potatoes were peeled with a stainless steel knife and the eyes removed in the usual way. After peeling they were placed in cold water and the whole sample was then cooked in an aluminium pan in boiling water, to which salt had been added (1 level dessertspoonful in 2½ pints of water). When adequately cooked the potatoes were drained and dished for immediate testing.

Method of Judging and Grading. The cooked potatoes were judged by a tasting panel of five under the headings given below. Scores from 0 to 5 were awarded by majority vote and values slightly above or below a given figure were indicated by + or — (equivalent to about ¼ + or —). External appearance, flesh consistency and flavour were judged immediately, and colour after the potatoes had stood for half-an-hour.

Colour : Complete absence of blackening and greyness was indicated by 5. Slight greyness or blackening in one tuber by about 4, definite blackening by 3, severe blackening by 2 and very severe blackening by 1 or less.

External appearance : The ideal potato was considered to have a firm but floury appearance shown by flaking of the outer layers. Marks were deducted from the maximum score of 5 for " soapiness " on the one hand or for excessive breakage or mushiness on the other.

Consistency : The scores for consistency largely followed those for external appearance as the scores were awarded on a basis of flouriness. Marks were deducted for a close-textured or sticky consistency, for mushiness or watery texture, or for the presence of lumps and variability.

Flavour : The highest score was given to samples with a distinct and pleasant potato flavour. Moderately good to insipid samples were given marks between 4 and 3, while definitely unpleasant samples were marked down to 2 or lower. Some samples were characterised by bitterness and were marked between 1 and 2.

DESCRIPTION OF CENTRES AND RESULTS

I. LONG ASHTON.

(a) Field Treatments.

The plots used at Long Ashton were those described in the previous experiments (1). The soil is a light, fine sandy loam with high content of lime and humus. Differential manurial treatments, with slight changes in rates, have been given continuously to the plots from 1928 to 1944, black currants being grown from 1928—1941, potatoes in 1942, a miscellaneous collection of indicator crops in 1943 and potatoes again in 1944. The manurial dressings on a per acre basis in 1944 were as follows :—

Treatment A — no manure.
" B — 10 tons stable manure.
" C — 3 cwt. sulphate of ammonia, 3 cwt. superphosphate, 2 cwt. sulphate of potash.
" D — as C, but nitrogen omitted.
" E — as C, but phosphate omitted.
" F — as C, but potash omitted.

Each of the above treatments was given in triplicate in three blocks and to one block, in addition, an over-all dressing of magnesium sulphate at 1 cwt. per acre was applied. Dressings of magnesium sulphate at rates varying from 3 to 4 cwt. per acre had been given to this latter block in previous years following the development of magnesium deficiency symptoms in the black currants. Five varieties of potato, viz. Majestic, King Edward, Gladstone, Arran Banner and Kerr's Pink, were planted on each plot, and with Majestic and King Edward two plantings were made, the second one month after the main planting, whilst samples of Majestic from the two plantings were lifted in August as well as at the normal harvesting time in October.

Observations made on growth during the summer showed that with treatments A and F the plants suffered severely from potash deficiency, whilst with treatment D, where nitrogen was omitted, the haulm was somewhat pale, indicating a mild deficiency of that element. Very slight symptoms of magnesium deficiency were present on the foliage in the blocks not receiving magnesium sulphate, particularly on the nitrogen omitted plots. Yield data for total tuber weights show clearly the acute potash deficiency on plots A and F and slight reductions from omissions of nitrogen and phosphate respectively.

(b) Results.

The results, showing the effects due to varieties, planting and lifting times and manurial treatments, are summarised in Tables I and II :—

TABLE I.

VARIETIES : AVERAGE SCORES FOR ALL TREATMENTS.

	Majestic. Aug. lifting.		Majestic. Oct. lifting.		King Edward.		Gladstone.	Arran Banner.	Kerr's Pink.
	Normal Plant	Late Plant	Normal Plant	Late Plant	Normal Plant	Late Plant			
Colour	3·2	3·6	3·4	2·9	3·5	3·4	4·1	4·0	4·2
External appearance ..	3·1	2·9	3·6	3·5	3·0	3·1	2·6	3·1	2·9
Consistency ..	3·3	2·4	3·3	3·6	3·5	3·3	3·6	3·4	3·4
Flavour ..	2·9	2·8	3·3	3·5	3·6	3·3	3·5	3·6	3·9

TABLE II.

MANURIAL TREATMENTS. AVERAGE SCORES FOR ALL VARIETIES AT OCTOBER LIFTING.

Treatment.	Nil	F.Y.M.	N.P.K.	P.K.	N.K.	N.P.	Nil	F.Y.M.	N.P.K.	P.K.	N.K.	N.P.	Nil	F.Y.M.	N.P.K.	P.K.	N.K.	N.P.
No.	A1	B1	C1	D1	E1	F1	A3	B3	C3	D3	E3	F3	A2	B2	C2	D2	E2	F2*
Colour ..	3·1	4·0	3·4	3·9	3·8	2·6	3·4	3·6	3·9	4·2	3·9	3·1	3·5	3·4	4·1	4·1	4·2	3·3
External appearance	2·9	2·9	3·4	3·1	3·4	2·7	3·2	3·0	2·9	3·3	3·4	3·0	2·9	3·1	3·2	3·0	3·1	3·2
Consistency	3·2	3·9	3·8	3·8	3·4	2·7	3·1	3·7	3·7	3·7	3·5	3·0	3·5	3·5	3·4	3·6	3·3	3·4
Flavour ..	3·1	3·9	3·7	3·8	3·4	2·7	3·4	3·8	3·9	3·7	3·4	3·2	3·9	3·6	3·6	3·9	3·6	3·4

* A2—F2 received Mg.

(1) *Varieties.*

The cooking quality of the crop lifted in October may be summarised as follows :—

Colour : Gladstone, Arran Banner and Kerr's Pink were of fairly good quality, blackening was slight (Table I) and was only appreciable in the low K plots. King Edward showed more blackening and was little better than Majestic, in which the blackening was most severe.

External appearance : No variety was good in this respect. Majestic received the highest score but was rather soapy. King Edward and Gladstone were rather mushy, Arran Banner very variable and Kerr's Pink wet and mushy.

Consistency : Little difference in score was shown, the ratings largely following those for external appearance. All showed variation within the sample.

Flavour : The flavour of the varieties was moderately good in all and there was little difference between scorings.

(2) *Effect of planting time.*

On the August lifting, Majestic planted at the normal time was better in general quality than when planted one month later (Table I), the latter being immature in character. Blackening was present in both series and was slightly greater in the normal plant. In the October lifting there was less difference in general quality between the two series, but the blackening was more serious in the late plant.

King Edward at the October lifting was little affected by the time of planting ; blackening was much the same in each series.

(3) *Effect of manurial treatments.*

Average scores for all the varieties taken together are shown in Table II, the averages being confined to the October harvest. In the duplicate Blocks 1 and 3 in which the plots did not receive Mg, blackening occurred most severely in the plots deficient in K (A, F). In Gladstone, Arran Banner and Kerr's Pink blackening was only appreciable in these plots. External appearance was poorest in the low K and F.Y.M. plots (A, B, F) and consistency in the low K plots (A, F), while low P also had some adverse effect (E). In Block 2, where Mg was added, the differences between treatments were less.

(c) Pot Experiment.

Tubers of the variety Majestic were grown in sand culture with the following nutrient treatments : complete nutrient (containing N, P, Ca, Mg, K, Fe, Mn, B) and complete nutrient minus each of the nutrient elements singly. Specially refined techniques were employed to produce deficiencies of Fe, Mn and B. As a result of the treatments visual symptoms of deficiencies of each of the elements were produced in the foliage of the appropriate cultures. The symptoms indicated very acute deficiencies of N, K and Mg and slight deficiencies of Ca, Fe, Mn and B.

The tubers were harvested on Nov. 13th, 1944 (with the exception of the —N cultures), and the boiling tests were made on Nov. 14th, 1944.

Cooking tests showed little variation in the quality of the tubers receiving the different treatments. The general level of quality was only moderately good in most respects, but the colour was excellent in all samples, no blackening occurring in any treatment. The tubers from the —N treatment were the most solid in consistency, but no other outstanding difference was seen between treatments. The tubers from the complete nutrient plots were better in consistency and flavour but showed no difference in the other respects.

II. OTHER CENTRES.

CENTRE A.

This centre is located in the Cambridgeshire Fens, the soil being described as a light Black Fen type. The field formed part of a recently reclaimed derelict Fen of deep peat, the lower horizons being frequently acid and containing the remains of trees. The majority of the samples were taken from a series of fertiliser plots in a factorial experiment to test dressings of N, P, K applied as sulphate of ammonia, superphosphate and muriate of potash. Each constituent was tested at three rates, viz. 0, $1\frac{1}{2}$, 3 cwt. sulphate of ammonia, 0, 5, 10 cwt. superphosphate and 0, $1\frac{1}{2}$, 3 cwt. muriate of potash. Other samples were taken from a second experiment adjoining the first in which excessively high rates of N, P, K were tested in various combinations ; 3, 6 cwt. sulphate of ammonia and muriate of potash, and 10, 15 cwt. superphosphate.

Observations on the growing crops showed that potash deficiency was the most serious limiting factor to growth and 3 cwt. muriate of potash appeared necessary to overcome visual symptoms of potash deficiency in the foliage. When potash deficiency was remedied phosphate deficiency symptoms were apparent.

The centre thus provided material from a peaty soil showing an outstanding deficiency of potash and a lesser, though acute, deficiency, of phosphate, to which were applied dressings of N, P, K ranging from normal war-time rates to others even higher than would be given under the highest conditions of potato culture in peace time.

The crops were lifted during the early part of September and the boiling tests made on October 27th, 1944.

Results.

Normal N.P.K. Treatments.

Quality was consistently poor in all respects, the potatoes being soapy, sticky and of poor flavour. As shown in Table III the average scores at the different N. P and K levels were from 1-3 and no treatment gave a sample of good quality. Blackening was extensive in all treatments and was most severe in the low K plots, the scores lying between 0 and 1. Potash appeared to be the only manurial factor to affect blackening, the averages ranging from 0·9 for K.O. to 1·8 for K.2 rates.

TABLE III.

CENTRE A. AVERAGE SCORES FOR TREATMENTS (LOW LEVELS).

	N O	N 1	N 2	P O	P 1	P 2	K O	K 1	K 2
Colour	1·3	1·2	1·4	1·2	1·4	1·4	0·9	1·2	1·8
External appearance ..	2·3	2·2	2·6	1·8	2·5	2·8	1·6	2·8	2·8
Consistency ..	1·5	1·5	1·9	1·1	1·8	2·0	1·8	1·7	1·7
Flavour	2·2	2·8	2·8	2·6	2·9	2·3	3·4	2·2	2·4

High N.P.K. Treatments.

The application of N, P and K at high levels in no case gave a potato free from blackening, all values being below 3·0 (Table IV), although the colour

scores were a little higher than in the series of normal dressings. The samples were also slightly more mealy and less sticky than those from the lower fertiliser levels. No treatment, however, produced a potato of satisfactory quality in any respect.

TABLE IV.

CENTRE A. AVERAGE SCORES FOR TREATMENTS (HIGH LEVELS).

	N 0	N 3	N 6	P 0	P 10	P 15	K 0	K 3	K 6
Colour	2·2	2·0	2·6	2·2	2·4	2·4	2·2	2·2	2·5
External appearance ..	2·9	2·9	2·6	2·2	2·9	3·1	2·0	2·4	3·2
Consistency ..	3·0	3·2	2·5	2·3	2·7	3·5	2·0	2·8	3·2
Flavour	2·5	3·4	2·1	2·3	2·1	3·4	2·5	3·0	2·5

CENTRE B.

The soil at this centre is a typical high-level Wold soil derived from a thin covering of Clay with Flints over Chalk. The surface soil contained over 2·0% carbonate of lime (pH 8·0) and was of average fertility as regards phosphate and potash as judged by soil analysis. This type of soil has only recently been used for potato growing and plots had been laid down to examine the manurial requirements of the crop on it. The experimental plots contained six varieties of potatoes to which sulphate of ammonia, superphosphate and muriate of potash were given in various combinations at the following rates per acre : sulphate of ammonia, 0, 3, 4½ cwt. ; superphosphate, 4 cwt. all plots ; muriate of potash, 0, 1½, 3 cwt.

Observations on the haulm showed that where potash was omitted, potash deficiency symptoms were severe, but they were generally absent where the 1½ cwt. KCl rate had been given, though it appeared that the higher rate of 3 cwt. KCl produced further response. Where nitrogen was withheld, deficiency symptoms of this element were shown.

In this experiment potash deficiency effects were again severe whilst nitrogen deficiency developed when both potash and phosphate were applied. Yield data also showed large responses from the potash dressings.

Samples of Majestic and King Edward were obtained for cooking tests. These were harvested during the second week in September and the boiling tests made on 25.10.44.

Results.

The general quality of the Majestic samples was from poor to moderate and blackening was appreciable in all (Table V). There was no clear effect of manuring on colour and nitrogen was not detrimental. Absence of K had a slight adverse effect on consistency, but otherwise no definite effect of manurial treatment was shown.

The King Edward samples were better than the Majestic samples and were fairly good. Blackening was slight and the general texture mealy. The only effect shown by manurial treatment was an adverse effect of low K on consistency and appearance.

TABLE V.

CENTRE B. AVERAGE SCORES FOR TREATMENTS.

	N 0	N 3	N 4½	K 0	K 1½	K 3
Majestic.						
Colour	2·5	2·8	3·7	2·9	2·7	2·8
External appearance	3·2	3·2	3·0	3·0	3·0	3·6
Consistency	3·0	3·0	2·9	2·4	3·2	3·0
Flavour	2·7	3·0	2·3	2·5	3·0	2·6
King Edward.						
Colour	3·7	3·7	3·8	3·7	3·7	4·2
External appearance	2·7	3·2	3·7	2·6	3·5	3·5
Consistency	3·7	3·7	3·8	3·3	4·2	3·8
Flavour	4·0	4·0	4·0	4·0	4·0	4·0

CENTRE C.

This centre is near Birmingham and is located on an area of typical grass heath land. The soil is derived from Bunter drift, being a typical podsolised, pebbly red sand, strongly acid in reaction. The samples were obtained from an area freshly broken up from heath conditions and utilised to test differential rates and methods of liming in combination with fertiliser dressings of varying N.P.K. contents.

The lime dressings were at the rate of 0, 3, 9 tons carbonate of lime per acre; on certain plots the dressings were applied as top dressings and on others they were ploughed in or partly on top and partly ploughed in.

The field observations showed that where lime was not applied, and especially in the absence of all fertilisers, there was practically no growth, whereas with lime alone phosphate deficiency was pronounced. Potash deficiency only showed where both lime and phosphate had been applied. The centre thus provided samples from plots very low in calcium and phosphate and with a slight potash deficiency. The variety was Majestic.

Harvesting was carried out on 12th October, and the boiling tests were made on 3.11.44.

Results.

Cooking Tests.

The quality as a whole was poor, the flesh of the tubers yellowish and sticky, and blackening was severe and generally distributed over the tubers in addition to the normal end blackening.

Blackening was not appreciably influenced by the additions of lime nor by the N.P.K. treatments. The tubers from the no-lime plots were small and no notable difference was found between the different N.P.K. treatments. The plots receiving 3 tons of lime per acre gave larger potatoes and the quality, although still poor, was slightly better than on the plots without lime. The plots receiving 9 tons of lime per acre showed no appreciable improvement

over the 3 ton plots, and from these the samples were stickiest from the low P and low N treatments. The average scores for all treatments of N.P.K. at the different lime levels are given in Table VI.

TABLE VI.

CENTRE C. AVERAGE SCORES AT DIFFERENT LIME LEVELS.

	Lime—Tons per acre.		
	0	3	9
Colour	2·0	1·9	1·9
External appearance	1·4	2·1	2·3
Consistency	1·5	2·3	2·3
Flavour	1·1	1·8	2·0

CENTRE D.

The samples from this centre were obtained from small laboratory-scale plots, approximately 1 sq. metre, on which an intensive study is in progress to test the effects of different manurial treatments and a range of pH values on farm crops grown in rotation. The soil is a light-textured, red sand of the Bridgnorth Series and is derived from Bunter Sandstone.

The manurial treatments comprise no fertiliser, N, P, K, N.P., N.K., P.K. and N.P.K. and the pH values range from pH 4 to pH 6, with an extra plot to study excess liming. The fertilisers used and rates per acre were 3 cwt. sulphate of ammonia, 3 cwt. superphosphate, 3 cwt. sulphate of potash. Two varieties, Kerr's Pink and Arran Banner were grown.

Foliage observations showed very acute symptoms of potash deficiency on all plots where this constituent was omitted, including no fertiliser treatment, whilst nitrogen deficiency was marked where this element was not given. No effects could be observed from omission of phosphate. On all plots where potash was applied and especially where nitrogen was omitted, symptoms of magnesium deficiency were shown. At the low pH values calcium deficiency was acute and growth severely stunted.

The plots thus provided marked deficiencies of potash, calcium and nitrogen but not of phosphate.

Harvesting took place at the beginning of October and the boiling tests were made on 6.11.44.

Results.

Cooking Tests.

In general the quality of both varieties was good, Kerr's Pink being superior to Arran Banner in consistency and flavour (Table VII). Typical blackening only occurred in the plots receiving N only, the colour scores being 2+ for Kerr's Pink and 3 for Arran Banner. The colour of both varieties was otherwise excellent. Samples from the plots which did not receive K were poorer in consistency and the Arran Banner samples also had a bitter flavour. For Arran Banner the scores for external appearance, consistency and flavour were highest in the plots receiving K and lowest in that receiving N only. In the Kerr's Pink samples flavour and consistency were less affected by fertiliser treatment, but the sample from the plot receiving N only was the most solid in consistency.

In the soil acidity series a lowering of pH produced no blackening but gave close-textured, sticky potatoes with a bitter flavour. Both varieties behaved similarly.

TABLE VII.

CENTRE D. AVERAGE SCORES FOR TREATMENTS.

	Arran Banner.			Kerr's Pink.		
	N	P	K	N	P	K
Colour	4·4	5·0	4·8	4·5	5·0	5·0
External appearance	3·3	3·5	3·9	3·4	3·7	4·1
Consistency	3·2	3·5	4·2	4·0	3·9	4·4
Flavour	3·3	3·5	4·0	4.0	4·1	4·0

CENTRE E.

This centre is in the Evesham area, on a market garden holding, the soil being classified as a Pershore Heavy Loam, which is derived from a mixture of Sand and Gravel Drift and Lower Lias Clay. The plots from which the samples were taken have been used continuously since 1939 for a manurial experiment on rotational vegetable crops. The fertility level is only medium, pH showing slight acidity, but there is no particular manurial deficiency. The manurial treatments per acre were as follows :—

1. 10 cwt. meat and bone, 4 cwt. muriate of potash.
2. As 1 but at $\frac{2}{3}$ rate.
3. 3 cwt. sulphate of ammonia, 4 cwt. superphosphate, 1 cwt. muriate of potash.
4. As 3 but $1\frac{3}{4}$ cwt. potash salts *vice* muriate.
5. As 3 but superphosphate omitted.
6. As 3 but 1 cwt. magnesium sulphate added.

The variety was Majestic.

Observations made on the foliage showed that growth was vigorous and healthy on all plots.

The tubers were lifted on 1.11.44 and the boiling tests made on 10.11.44.

Results.

Cooking Tests.

The quality as a whole was moderate (Table VIII) and all samples showed a slight but definite end blackening. The manurial treatments produced no outstanding differences in consistency ; all samples were mealy but rather watery and lumpy. No differences were seen between the tubers from plots receiving organic and inorganic N respectively.

TABLE VIII.

CENTRE E. AVERAGE SCORES FOR TREATMENTS.

	N and K.	P.
Colour	3·1	3·0
External appearance	3·1	3·1
Consistency	3·2	3·4
Flavour	3·0	3·0

CENTRE F.

The soil is a typical loam of the Cotswold area, derived from the Inferior Oolite Formation but devoid of brash. It contains over 2% $CaCO_3$ and analysis showed "Available" P_2O_5 0·016% and "Available" K_2O 0·005%, the latter value being low.

The samples were taken from a series of plots to which had been given, in addition to an overall dressing of a potato fertiliser at 8 cwt. per acre, differential dressings of sulphate and muriate of potash respectively in combination with progressive rates of superphosphate. The potash and superphosphate dressings were both at rates of 0, 1, 2, 3 cwt. per acre.

Growth on all plots was noted to be vigorous throughout the season and no deficiency symptoms were seen in the haulm. It may be that the basal manurial dressing applied to all plots was sufficient to prevent the occurrence of appreciable deficiency effects. The crop weights showed no consistent effects on yields apart from a possible depression from muriate of potash, although this cannot be certain owing to the design of the plots. The variety was Majestic. Harvesting was carried out on 2.11.44 and the boiling tests were made on 5.12.44.

Results.

Cooking Tests.

The samples were of a solid and starchy consistency but were not soapy. The quality as a whole was moderate (average scores 3–4) and the series was characterised by an unpleasant "mineral" taste. Blackening was general and very definite (values 2–3), but little difference was seen at the different P and K levels, being only slightly more severe in the plots receiving no K. No other effects of fertiliser treatment were observed.

CENTRE G.

This centre is located at Stourport, Worcestershire, on an area, previously grass, used as vegetable allotments during the war. The soil is a light-textured red sand, strongly acid in reaction and on which vegetable crops have shown many failures from acute potash deficiency. Plots with progressive dressings of muriate of potash were laid down in 1943 to demonstrate the benefits of this fertiliser on potatoes, when the interesting point was observed that with adequate dressings of potash, calcium deficiency became pronounced. The treatments were repeated in 1944 when similar observations were made. The beneficial effects of the potash dressings are clearly shown in the average yields of tubers of Majestic from duplicate plots in 1944 : no potash, 56 lb. ; 2 cwt. muriate, 138 lb. ; 4 cwt. muriate, 139 lb. ; 6 cwt. muriate, 123 lb. Harvesting was carried out about mid-October and the boiling tests were made on 2.11.44.

The centre thus provides soil conditions of strong acidity (pH 5·3), together with acute potash deficiency and the effects of heavy potash dressings applied to remedy the latter circumstance.

Results.

Cooking Tests.

Quality as a whole was poor (average scores about 2). Severe blackening occurred at all levels of treatment and was not affected by the addition of potash.

Consistency and flavour were lowest in the plot which did not receive potash but the differences were small.

GENERAL DISCUSSION.

Varieties.

Samples of Majestic were obtained from seven centres and at no centre did the variety reach a high level of quality as judged by cooking tests. Blackening was general and was present in all batches. The samples from the Long Ashton plots received the highest scores although blackening was very definite in certain plots. The scores for colour, appearance, texture and flavour lay mainly between 3 and 4. The samples from the Evesham area (E) were similar in quality, as also were those from the pot experiment at Long Ashton. The latter samples were exceptional in that no blackening occurred. The samples from sites B, C and F were inferior to the Long Ashton samples, average scores for all characters lying between 2 and 3 ; blackening was serious with average scores of 2·8, 1·9 and 2·6 respectively, and the highest values for colour for these three centres were respectively 3, 3+ and 4. The samples from site A were of very poor quality and blackening was severe, the average colour score being below 2. The only plot giving potatoes with a higher colour score was one of those receiving the highest rate of fertiliser application and here the score only reached 3+.

King Edward was grown at two of the centres, at Long Ashton and at site B. At Long Ashton this variety differed little from Majestic in general scores for quality, and blackening was similar in both varieties. At site B, King Edward was much superior to Majestic in all respects. Blackening was slight at site B, even though Majestic showed more blackening at this site than when grown at Long Ashton.

Gladstone was only grown at Long Ashton and was found not greatly different from King Edward although blackening was less. Samples of Arran Banner and Kerr's Pink were obtained from Long Ashton and from site D. At the former site both varieties resembled Gladstone in general quality. At the site D, Arran Banner and Kerr's Pink were better in general quality than when grown at Long Ashton and the colour was excellent except in those plots receiving N only.

Time of Planting and Lifting.

Evidence has been brought forward by Smith, Nash and Dittman (2) that blackening in cooked potatoes is less when the tubers mature at high temperatures than when they mature at low temperatures, *i.e.* that early planted potatoes maturing during the hottest part of the late summer are less liable to blacken than late planted potatoes maturing during autumn. To determine the influence of planting date at Long Ashton two plantings of Majestic and King Edward were made and the former were lifted in August and at the normal harvest in October.

At the early harvest the Majestic planted early showed slightly more blackening than when planted one month later, the latter tubers being immature in character. At the normal harvest the late plant showed definitely more blackening than those planted at the normal time, the general intensity of blackening being greater in all samples. The two plantings differed little in other quality scores. The two plantings of King Edward, on the other hand, showed little difference either as regards blackening or quality in general.

The general incidence of blackening in all samples of Majestic, a variety known to be liable to the defect, may be related to the low temperatures prevailing during the 1944 season. It may be significant that the only samples which did not blacken were those grown in pots at Long Ashton under glass, where the mean temperature would be higher.

Site Effects.

The relation between quality and the site at which the potatoes were grown is shown by the behaviour of the variety Majestic at the sites described. The average colour scores for the N.P.K. treatments at the different centres are shown in Table IX, and these give a fair indication of the general quality of the crops as a whole. Quality differences due to site were considerable, and where it was possible to compare a given variety at different sites under various manurial treatments, site effects were greater than those due to manuring. As shown in Table IX, Majestic grown at Long Ashton without the addition of fertiliser had an average colour score of 3·1. At centres A and C the corresponding treatment, *i.e.* no addition of fertiliser, gave ratings of 2·0 and 1·9 respectively. Adverse manurial treatment (N.P.) only lowered the colour score to 2·7 at Long Ashton ; on the other hand similar treatment at site A gave tubers with an average score of 1·0, while the addition of " N only " reduced the score to 0·2. The highest colour scores at Long Ashton were obtained in the P.K. treatments, viz. 4·3, but this treatment at site A produced no improvement above the general level. The different manurial treatments at sites B and C did little to shift the colour scores outside comparatively narrow ranges.

The scores for blackening at the different sites thus lie within fairly narrow ranges which appear characteristic for the sites. On the Long Ashton plots the degree of blackening has not been appreciably reduced by adverse manurial treatment but has been raised by P.K. additions. At site A the general level of quality was only slightly raised from the lowest level even by the application of impracticably large amounts of fertiliser (*c.f.* Table IV).

Unless factors such as the climate during the autumn of 1944 are to be considered mainly responsible for the low quality of the Majestic samples, the tests suggest that certain sites are definitely unsuitable for potatoes, or at any rate for varieties like Majestic which are liable to blacken. The growing of other varieties may however be possible on some sites ; *e.g.* on a site of intermediate character such as B, King Edward was found to be of fairly good quality, although Majestic on that site was relatively poor (see Table V above). The influence of planting date should also be considered and may be decisive at some doubtful sites : as shown in Table IX, late planting on the Long Ashton plots had a definite deleterious effect as regards blackening and produced a greater effect than did the manurial treatments.

TABLE IX.

MAJESTIC. BLACKENING AT DIFFERENT SITES.

Treatment.	N.	P.	K.	P.K.	N.K.	N.P.	N.P.K.	nil.
Long Ashton—Normal plant	—	—	—	4·3	3·6	2·7	3·5	3·1
Long Ashton—Late plant	—	—	—	3·0	3·0	2·1	3·0	3·0
Centre A	0·2	0·7	1·4	1·4	1·4	1·0	1·7	2·0
Centre B	—	3·0	2·2	2·1	—	3·0	2·7	—
Centre C	—	1·7	2·0	2·0	2·3	1·7	1·6	1·9

Manurial Treatments.

The centres provide examples of widely differing soil conditions and nutritional status, together with a wide range of manurial treatments. At Long Ashton potash deficiency was severe and nitrogen deficiency was also in evidence, and it was possible to examine the effects of dressings of various combinations of N.P.K. and of farmyard manure. At centre A on a recently reclaimed Fen soil potash deficiency was acute and a secondary phosphate deficiency appeared when the potash shortage was rectified. Dressings of N.P.K. in various combinations and at both ordinary and exceptionally high levels, were given. At B where the soil is of average arable fertility, potatoes showed acute potash deficiency and a secondary deficiency of nitrogen. At C on a recently reclaimed heath soil, there were acute deficiencies of lime and phosphate and only a slight deficiency of potash. It was possible here to examine the effects of normal and high dressings of lime and of various N.P.K. treatments. At D there was a very wide range of acidity and N.P.K. treatments on a soil of high repute for potato culture. Centre E is an example of a good arable soil on which a variety of possible N.P.K. complete fertiliser treatments were given. At F, located on a typical Oolite soil of low fertility, differential K and P treatments were tested. G is an instance of a poor, acid soil with an acute deficiency of potash where the effects of potash and lime dressings were observed.

Large yield responses from potash manuring were obtained at six centres, but the effects on quality factors were small and inconsistent. At Long Ashton, A and D blackening was decreased by potash, although this effect at A, where blackening was very severe, was relatively small and even 6 cwt. KCl per acre failed to raise the average value to 3. At D blackening only occurred where the treatment " N only " was applied and not where N.P. was given so that it might appear that phosphate prevented blackening. At centres B, C and G, where blackening was either medium or severe, no improvement was effected by potash. At certain centres, notably Long Ashton and A, potash deficiency was associated with poorer external appearance and flesh consistency.

Nitrogenous manuring has often been previously associated with increased blackening and, although this has occurred at centres Long Ashton and D in these experiments, such effects from nitrogen have not been consistent and no generalisation can be made regarding this point. On the other hand, some of the best samples as regards freedom from blackening have been obtained where nitrogen was omitted from the fertiliser. Nitrogen deficiency was also associated with close-textured tubers and an inferior immature flavour at some centres.

Noticeable effects associated with phosphate deficiency have been poorer external appearance, close and sometimes sticky flesh consistency and a bitter flavour. The only instance where phosphate may have affected blackening was at centre D, where N.P. treatment gave no blackening and N only severe blackening.

Calcium deficiency at centres C and G did not seem to affect blackening, which was severe on all plots. At C lime seemed to improve slightly external appearance, flesh consistency and flavour.

At the two centres E and F, where complete fertilisers had been given to all plots, the differential treatments showed no effects on the quality factors.

In view of these results it can only be concluded that the widely differing manurial treatments have only produced relatively small effects on quality,

and in particular it is evident that none of them can be relied upon to solve the blackening problem where it is serious. Where blackening has been decreased, potash manuring has always been associated with the improvement.

It should also be noted that deficiencies of either N, P or K tended to produce adverse effects on external appearance, consistency and flavour, which were suggestive of immaturity of the tubers.

CONCLUSIONS.

Differences in potato quality due to site, variety and manurial treatment have been brought out in the present tests and the effect of site and variety has been found greater than that due to manurial treatment. At some centres the variety chiefly studied, Majestic, has been found consistently poor and no manurial treatment has raised the general level of quality to any appreciable extent. The application of even excessively large quantities of fertiliser has not succeeded in producing a good potato at such a centre.

Where a deficiency of a particular element has been noted, the addition of that element had produced an increase in growth and yield and also an improvement in quality, although the latter has been relatively small and limited by the character of the site. In a similar manner, an unbalanced fertiliser treatment on one of the better sites has produced an adverse effect on yield and quality, but at the same time the quality of such potatoes has usually been better than those receiving a balanced application of fertiliser on an unfavourable site.

The comparison of different varieties at a particular site has shown a variable degree of response to manurial treatment. While a variety prone to blacken, such as Majestic, has proved susceptible to adverse soil conditions, other varieties have shown themselves less easily affected. For example, while King Edward has differed little from Majestic in quality at Long Ashton, where both were moderately good, on poorer soil at site B, King Edward was much superior to Majestic. Arran Banner and Kerr's Pink showed even less susceptibility to blacken on cooking and at site D this only occurred under an unbalanced treatment high in N.

The present findings therefore suggest it to be more profitable to find a variety which will give a reasonable response at a particular centre than to attempt to improve an unsuitable variety by manurial treatment.

According to the American workers (2) cooking quality, particularly with regard to blackening, has been found influenced more by the temperature during the latter part of the growing season than by nutrition. Tubers maturing at temperatures above 70° F. showed little blackening, while at temperatures below 60° F. blackening was widespread. They accordingly suggested the increased use of varieties which matured earlier in the season, or where practicable, earlier planting dates of the later varieties.

In the present series of tests, Majestic planted late showed more extensive blackening than when planted at the normal time. King Edward on the other hand showed little effect. Further studies on the effect of planting dates are to be carried out using a wider range of varieties.

SUMMARY.

1. A study has been made of the cooking quality of potatoes grown at eight centres, with special reference to the incidence of blackening on boiling.

2. The sites comprised a variety of soil types combined with deficiencies of N, P, K, Ca and Mg, and the effects of manurial treatments, varieties and planting times have been described.

3. The quality of the potatoes has been found to depend more upon the character of the site than upon the manurial treatments which have been applied.

4. On poor soils it has not been possible to obtain potatoes of good quality or even to bring about any substantial improvement in quality by a wide range of manurial treatments or by the application of very large amounts of fertiliser. Where some improvement has taken place, it has been associated with potash manuring.

5. On the better types of soil, potato quality has been little affected by manurial treatment except where actual deficiencies have arisen or been provoked. Deficiency of K has been associated with an increase in blackening, while deficiency of P has caused deterioration in flesh consistency and flavour.

6. The varieties Majestic, King Edward, Gladstone, Arran Banner and Kerr's Pink have been found to differ in general quality and in their susceptibility to blackening. It is suggested that the choice of suitable varieties would go far to alleviate the blackening problem.

7. The effect of planting time has been discussed and adverse effects following late planting have been described.

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A COMPARISON OF METHODS OF PRESERVING FRUIT

By ALICE CRANG, M. CROXALL, D. P. JAMES & M. STURDY.

Various methods of preserving fruit by bottling, canning and the preparation of fruit syrups have been recommended for some time, but little information has been available to compare the quality of the stored products. These experiments were therefore carried out to compare :—

(*a*) The general quality of the stored fruit, including its flavour, colour and texture.

(*b*) The jam-making quality of the fruit, including its acid and pectin contents after storage; and the set, flavour and colour of the jam made from it.

(*c*) Methods of making syrups from suitable fruits.

Originally it was intended to compare the amount of ascorbic acid retained in the various preserved fruits, but this was abandoned after certain workers had found that the recognised method for determining ascorbic acid then in use might give erroneous results with preserved products (1) (2).

Materials and Methods.

The Fruit.

The following 25 samples of fruit were preserved :—

Apples (1), blackberries (wild and cultivated), black currants (2), cherries (black, white and Morello), damsons (1), gooseberries (2), loganberries (3), plums (2), raspberries (2), red currants (2), rhubarb (1), and strawberries (4).

In each case the fresh fruit was preserved and analysed on the same day.

Methods of Preserving.

The fruit and water or syrup was weighed into each container using the same proportions of fruit and liquid. Preserving bottles with rubber rings and glass tops held in place by a screw band, or cans with fruit-resistant lacquer, were used. The syrups were stored in glass syrup bottles with corks waxed after sterilizing.

The methods of preserving were as follows :—

1. *Slow-Water.* The bottles of fruit and water were sterilized by immersing in water, bringing the temperature up from cold to the required level in $1\frac{1}{2}$ hours and maintaining it there for 10—20 mins. according to the fruit.*

2. *Slow-Syrup.* The fruit covered with 30° Brix. sugar syrup instead of water was sterilized as in 1.

3. *Oven.* The bottles of fruit were heated in an oven*, then removed and boiling water added in the same proportion as in 1 before quickly sealing the jars.

4. *Quick.* The bottles of fruit and warm water were placed in a water bath at 120° F., the water brought to the boil in 35 mins. and the jars kept in the boiling water for a further 5 minutes.

5. *Canned-Water.* The cans were filled to within $\frac{1}{8}$ in. of the top with fruit and boiling water, in the same proportions as in the bottles, the lids sealed on and the cans sterilized in boiling water*.

6. *Canned-Syrup.* The fruit and 30° Brix. sugar syrup in place of the water were treated as in 5.

7. *SO_2.* The fruit was weighed into the bottles, covered with a cold solution of sulphurous acid containing 1000 p.p.m. SO_2 and the lids screwed down.

8. *KMS.* The fruit treated as in 7, but a solution of potassium metabisulphite, containing the equivalent of 1000 p.p.m. SO_2 used instead of the sulphurous acid solution.

9. *NaMS.* The fruit treated as in 7, but a solution of sodium metabisulphite, containing the equivalent of 1000 p.p.m. SO_2 used instead of the sulphurous acid solution.

The methods of preparing the fruit syrups were as follows :—

10. *Slow-Sterilized.* The crushed fruit was heated in a pan over boiling water until soft, strained, and $\frac{3}{4}$ lb. sugar added to each pint of juice. The syrup in bottles was sterilized for 30 mins. at 170° F. Water was used in extracting the juice from black currants and blackberries.

11. *Quick-Sterilized.* The crushed fruit was brought to the boil as quickly as possible, boiled for 15 minutes, strained, sugar added and the syrup sterilized as in 10. The same proportion of water was used in extracting the juice from black currants and blackberries.

12. *Enzyme-Sterilized.* " Pectinol ", a pectin-decomposing enzyme, was

* For times and temperatures see Ministry of Agriculture Bulletin 21, 1944 edition.

mixed with the crushed fruit at the rate of $\frac{1}{3}$ oz./10 lb. fruit and the fruit left until fermentation was about to begin (usually 2 days). It was then strained, sugar added and the syrup sterilized as in 11.

13. *Enzyme-Preservative.* The juice was extracted after leaving the fruit with " Pectinol " as in 12, the sugar added and the syrup preserved with 350 p.p.m. sulphur dioxide, added in the form of either sodium or potassium metabisulphite.

The sugar concentration ($\frac{3}{4}$ lb. sugar to 1 pint juice) was the same in each of the syrups.

Storage.

The preserves were stored together during most of the time at about 60° F., but the temperature rose to approximately 10° above the prevailing temperature for short periods, especially during the summer months, and 90° F. was reached on a few days each year. These conditions would therefore be more severe than those normally found in the home where preserves are stored.

The result of the high temperature would be to accelerate the corrosion of tin plate causing " hydrogen swells " to occur more readily. Hirst and Adam (3) have shown that the " life " of cans of fruit stored at 75° F. is approximately one-half of those stored at 55—60° F., whereas it is reduced to about one-quarter when stored at 90° F. It was to be expected therefore that some loss of the canned fruits under test would occur. The fluctuating temperature also gave the fruit stored with sulphur dioxide preservative a severe test, since changes in temperature would cause some leakage of the preservative from the jars. The minimum time of storage before analysis in the first year's series was 7 months, and the maximum 21 months. In the series preserved the second year, the minimum storage time was 12 months and maximum 21 months.

The different preserves from each lot of fruit were analysed as soon as possible after the first one of that series had been opened.

Methods of Analysis.

The preserved fruits were weighed when the container was opened, and any loss of liquid which had occurred during sterilizing was allowed for in calculating the pectin and acid retained. In those fruits which contained stones, the proportion of flesh to stone was determined both in the fresh and preserved fruit, and analysis carried out on the stone-free product. In all cases the analysis was carried out in duplicate.

The pectin determinations were made, using the standard Carré and Haynes' method of precipitating the pectin as calcium pectate. In those fruits where the results seemed higher than expected, the pectin was precipitated first with acetone (4), but in most cases the agreement between the two methods was so close that the initial precipitation with acetone was not continued.

The acidity was determined by a straightforward titration of the diluted sample after boiling for at least $\frac{1}{4}$ hour and cooling. Phenolphthalein was used as an external indicator.

Before tasting the fruit preserved in water was cooked with sufficient sugar to bring the concentration up to that of the fruit preserved in 30° Brix sugar syrup. The flavour was assessed by a panel of tasters.

Jam from the fresh fruit was made, using the same proportion of fruit and liquid as in the preserved jars. The fruit and liquid (or contents of the

jar or can) were boiled down to a predetermined weight, sugar added, and the jam reduced until its weight was $\frac{5}{3}$ that of the sugar used. The soluble solids content of the finished jam was determined by refractometer and unless the results were close to the original figure, the results of the " flow " were not recorded.

The " flow " or setting quality of the jam was tested as follows :—A glass cylinder, $7\frac{1}{2}$ cm. length and 3 cm. diameter was placed on a glass plate under which was a chart of concentric circles; $\frac{1}{4}$ inch to 3 inches radius. The cylinder, placed concentrically over the chart, was filled with jam, which had been well mixed. The cylinder was then raised $\frac{1}{2}$ inch and the spread of the jam measured in 4 sectors after 1 minute ; the firm jams giving a relatively small reading and those which were weaker spreading more quickly. The jams were tested 24 hours after they were made and at the same temperature as the original jam made from fresh fruit, thereby giving a comparison of the set of the jams made from fresh and preserved fruits.

Results.

A. Quality of Stored Fruit.

(a) Keeping Quality.

The condition of the fruit preserved by heat sterilizing in bottles (methods I to IV), heat sterilizing in cans (methods V and VI) and preserving with sulphur dioxide in the cold (methods VII to IX), for the two seasons were as follows :—

	Stored less than 12 months. Av. 7½ months.		Stored more than 12 months. Av. 18 months.	
	No. of Samples.	No. satisfactory.	No. of Samples.	No. satisfactory.
Heat sterilized in bottles	21	18 (86%)	119	117 (98%)
Heat sterilized in cans	14	13 (93%)	58	43 (74%)
SO_2 preserved in the cold. Soft fruits	57	46 (81%)	50	23 (46%)
SO_2 preserved in the cold. Stone or hard fruits ..	—	—	40	34 (85%)

The five failures in the heat preserved bottles were probably due to faults in the jars or rings, as slight mould growth had occurred on the fruit. The proportion of failures is higher than generally expected in this method of preserving.

The high proportion of cans unsatisfactory after long storage was due to the cans becoming " blown " from hydrogen swells, owing to the high temperatures of storage of the fruit during two summer periods.

It was hoped to include analysis of blackberries in the fruit comparisons despite the fact that they are known to give unsatisfactory results when preserved by sulphur dioxide in the cold, but the twelve jars of fruit (6 wild and 6 cultivated) preserved in this way, had all fermented within 18 months of storage, thus accounting for 24% of the failures in the soft fruits stored for more than 12 months.

The proportion of failures was almost the same whether sulphurous acid, potassium metabisulphite or sodium metabisulphite was used as the source of sulphur dioxide in preserving fruits.

(*b*) *Flavour.*

Sixteen fruits, bottled in water and sterilized by the various methods, were tasted. In ten, the "Slow" process method gave the best flavoured product and in the other six the fruit preserved by this method was similar in flavour to that subjected to the other methods of heat sterilizing. The "Slow" process was therefore used as the standard of flavour.

Method of Preserving.	Better than "Slow-Water."	Similar to "Slow Water."	Poorer than "Slow-Water."
II. "Slow-Syrup"	5	–	–
III. "Oven"	–	–	6
IV. "Quick"	–	1	7
V. "Canned-Water"	–	5	9
VI. "Canned-Syrup"	2	–	4
VII. "SO_2"	–	3	9
VIII. "KMS"	2	–	6
IX. "NaMS"	2	1	6

It will be noticed that the fruits preserved in syrup were generally preferred to those preserved in water and sweetened just before tasting.

Four of the six "Oven" preserved fruits were said to be "nearly as good" as the "Slow-Water" preserved ones. Four of the "Canned-Water" fruits had a slight "metallic" flavour, due to the cans beginning to develop hydrogen swells before they were examined.

Three of the six kinds of fruit canned in syrup were considered to be better in flavour than the corresponding fruits canned in water, and the other three similar to them.

(*c*) *Colour.*

The colour of the preserved fruits has been tabulated in the same way as the flavour:—

Method of Preserving.	Better than "Slow-Water."	Similar to "Slow-Water."	Poorer than "Slow-Water."
II. "Slow-Syrup"	3	2	–
III & IV. "Oven" and "Quick"	–	All fruits	–
V. "Canned-Water"	–	3	10 Slight "blue" colour
VI. "Canned-Syrup"	2	2	2 do.
VII, VIII & IX. "SO_2" "KMS" & "NaMS"	2	4	15

Half the fruits preserved in syrup retained a better colour than those in water, the others being similar.

Blue discoloration was noted in a number of the canned fruits.

Fruits containing anthocyanin pigments when preserved with sulphur dioxide had the colour bleached during storage, but much of this returned after cooking; even so the colour was generally poorer than the comparable heat sterilized fruits. There was little difference in colour whichever method of adding the preservative was used. The bleaching effect of the sulphur dioxide improved the appearance of apples.

(*d*) *Texture.*

The texture of the fruit preserved in water by the slow method or by canning was in all cases good, the fruit being whole and tender; that preserved in water by the "Oven" and "Quick" methods was rather more broken. The fruit was said to be slightly tough in one sample when bottled in syrup and in two samples when canned in syrup, but the others were quite satisfactory.

The texture of the black currants, cherries and gooseberries was not so good in the fruit preserved with sulphur dioxide as with the "Slow-Water" method, owing to the skins becoming toughened, as was expected. There seemed little difference in the toughening effect of the three preservatives used. The texture of the other fruits preserved by this method was satisfactory.

B. Jam-Making Quality.

(*a*) *Acid Content.*

There was no significant change in the total acidity of the heat sterilized fruits but a slight increase in those preserved with sulphur dioxide or sodium metabisulphite. The following figures indicate the general trend :—

Method of Preserving.	Average Acid. % of original.	Number of Fruits.
I. "Slow-Water"	98	12
II. "Slow-Syrup"	104	10
III. "Oven"	102	9
IV. "Quick"	100	14
V. "Canned-Water"	99	16
VII. "SO_2"	108	8
VIII. "KMS"	98	7
IX. "NaMS"	107	8

In another series of 16 samples preserved in water and in syrup, those in water had less than 2% more acid retained in the stored product than those in syrup. This amount is within the experimental error.

(*b*) *Pectin Content.*

A comparison of the pectin content of the stored preserved fruit with the original quantity determined on the fresh fruit is given in the following table. Allowances have been made for the amount of liquid used and any lost during sterilising.

Method of Preserving.		Pectin % of Original.		Number of Fruits.
		Average.	Range.	
I. "Slow-Water"		103	73–133	11
II. "Slow-Syrup"		92	79–105	3
III. "Oven"		105	70–135	8
IV. "Quick"		109	84–144	8
V. "Canned-Water"		111	93–148	7
VII. "SO_2"	Soft fruit & Cherries	32	7– 67	13
	Plums & Damsons	80	58–101	2
VIII. "KMS"	Soft fruit & Cherries	26	13– 56	9
	Plums & Damsons	86	60–112	2
IX. "NaMS	Soft fruit & Cherries	27	5– 57	14
	Plums & Damsons	81	58–103	2

It will be seen that there is an appreciable increase in the apparent pectin content of some of the fruits after sterilizing and storage. This suggests that hydrolysis of some of the precursors of pectin occurs as a result of the heat trestment in the presence of acid from the fruit.

The serious loss of pectin in the soft fruits preserved in the cold with sulphur dioxide is outstanding, there being little difference whichever of the methods VII and IX was used ; the Victoria plums analysed gave no apparent loss of pectin, the range being 101% to 112% pectin retained compared with 93% to 109% in the heat sterilized fruits ; the amount of pectin retained in the damsons and apples was higher than in most of the other fruits.

(*c*) *Setting Quality.*

The figures obtained for the "Flow" of jams made from the preserved fruit would be higher than the original figures for jam made from fresh fruit if the jam were weaker in consistency. The reciprocal of the percentage "flow" of jam made from preserved fruit, compared with that of the jam from the fresh fruit, is therefore given, to facilitate a comparison of the pectin content and setting quality.

Method of Preserving.	Reciprocal of "Flow" of Jam, % of Original.	Number of Samples.
I. "Slow-Water"	117	9
III. "Oven"	123	7
IV. "Quick"	131	6
V. "Canned-Water"	161	5
VII. "SO_2"	48 (Soft fruits)	11
VIII. "KMS"	76 (Plums & Damsons)	5
IX. "NaMS"		

A comparison of these figures with the amount of pectin found in the stored fruit shows that the slight increase in pectin content generally found in the heat sterilized fruits corresponds to an increase in the setting quality of the jam. The decrease in pectin of soft fruits preserved with sulphur dioxide is correlated with very definite decrease in the setting quality, while the plums and damsons show some decrease in setting quality, but this is not so severe as with the soft fruits.

There was no significant difference between the setting qualities of fruit preserved with sulphur dioxide, potassium metabisulphite or sodium metabisulphite.

(*d*) *Flavour of the Jam.*

None of the heat sterilizing methods was outstanding from the point of view of flavour of the jam made from it, and these jams were generally slightly inferior to those made from the fresh fruit and stored for the same length of time. They were all, however, of better flavour than the jam made from sulphur dioxide preserved fruits excepting the plums, which retained a good plum flavour in the jam.

(*e*) *Colour of the Jam.*

The colours of the jams made from heat sterilized fruit and from fresh fruit were generally similar after the same length of storage. The jams made from fruit preserved with sulphur dioxide were generally lighter in colour, but not necessarily less attractive on that account.

C. Fruit Syrups.

Fruit syrups were made by methods X, XI, XII and XIII from the following nine fruits: blackberries (wild and cultivated), black currants (2), loganberries, raspberries (2), red currants and strawberries.

Flavour.

In each of the fruits the syrup prepared by method X, gently heating the crushed fruit and sterilizing the syrup, gave the best flavoured product. The juice extracted by boiling the fruit was preferred to the juice extracted by breaking down the fruit in the cold with an enzyme, the latter giving a slightly " foreign " flavour to several of the syrups and in others the product had a slight fermented taste.

The syrups which were heat sterilized were preferred to those preserved with sulphur dioxide in the cold, even when diluted so that the concentration of sulphur dioxide was not excessive. The panel of judges were all, however, experienced tasters and sensitive to sulphur dioxide in products.

Colour.

There was little difference in colour between the syrups prepared by heating the fruit slowly or quickly, but all heated products were better than those which received the enzyme treatment. As would be expected with red-coloured fruits, the heat sterilized syrups retained a better colour than those preserved with sulphur dioxide, all of which showed permanent bleaching of some of the red colour.

Discussion.

The " life " of fruit preserved in bottles by any of the methods of heating should be indefinite provided that the bottles were adequately sterilized and sealed. On the other hand, fruits in cans develop " hydrogen swells " after prolonged storage, particularly if they are stored in warm places; and those

preserved with sulphur dioxide are not hermetically sealed, so that the preservative tends to escape when there are fluctuations in temperature. These conditions prevailed for the storage period of this experiment.

A comparison of various methods of preserving has been attempted on a range of fruits. Some of these are not generally considered suitable for preserving with sulphur dioxide, but were included for the sake of completeness. A high proportion, particularly of soft fruits so preserved, developed mould or fermented after the average storage time of 18 months. The strawberries, although generally considered suitable for storing by the sulphur dioxide method, gave a high proportion of failures after 18 months' storage (33%). The stone fruits and apples were more satisfactory, but even so there is a greater risk of spoilage than if heat sterilizing methods are used. There was little difference in the results whichever method of adding the sulphur dioxide was used.

The quality of the fruit preserved in bottles by slowly sterilizing them in water was the best as regards flavour and texture, and similar to the other heat sterilizing methods in regard to colour. The fruit which was preserved in sugar syrup was superior in colour and flavour in about half the fruits to the comparable ones preserved in water, whether bottled or canned. There was little difference between the quality of the fruit preserved by the " Quick " method in water and that treated by heating the fruit in the oven, both being more broken and slightly poorer in flavour than the slowly sterilized fruits.

It was unfortunate that a large proportion of the canned fruits were becoming " blown " at the time of analysis, due to the high storage temperature, as this affected the colour and flavour of the fruit.

The colour, flavour and texture of the fruits preserved with sulphur dioxide were generally inferior to those in the fruits preserved by other methods, although this was not so noticeable with the stone fruits and apples as with the soft fruits.

It is often said that fruits preserved in water increase in acidity during storage. This was not found to be so, there being no significant change in the acidity of the fruit stored in water and syrup, so the apparent increase of acidity in the former is probably due to a dilution of the sugar content of the fruit.

The retention of pectin and setting quality in the heat sterilized fruits was good—in several instances this appeared to be better than in the original fruits—on the other hand the losses in pectin and setting quality of fruits preserved in the cold with sulphur dioxide were severe, though plums, damsons and apples retained much more than most of the other fruits tested.

It would seem therefore that preserving fruits in sulphur dioxide in the cold for use later in jams should be confined to stone fruits and apples.

As regards colour and flavour, the " enzyme " method of softening the fruit in domestic fruit syrup-making did not compare favourably with extraction of the juice by heating, particularly if the latter was carried out below simmering point. The heat sterilized syrups were also preferred to those preserved with sulphur dioxide.

Summary.

1. A comparison has been made of fruits preserved by nine different methods of bottling and canning and four methods of making fruit syrup.

2. The sterilization of fruit by heat was more reliable than preserving it in the cold with sulphur dioxide.

3. Fruits sterilized in bottles by slow heating in water were generally superior in quality to fruits preserved by the other methods.

4. The pectin and setting quality of the fruit for jam-making was satisfactory in products preserved by the heat methods, but there was, in most cases, a considerable loss of both in the fruits preserved with sulphur dioxide in the cold. This was greater in the soft fruits than with stone fruits and apples.

5. Fruit syrups made by slowly heating the fruit to extract the juice were preferred to those in which the fruit was softened in the cold with a pectin-decomposing enzyme. The flavour of the heat sterilized syrups was also preferred to those preserved with sulphur dioxide.

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NOTES ON DOMESTIC APPLE JUICE PRODUCTION.

By ALICE CRANG and M. CROXALL.

During the last year there has been a considerable increase of public interest in unfermented apple juice in this country, and enquiries have been received from a number of sources as to possible methods of preparing such a drink in the home or on small holdings.

Experiments on the production of apple juice on a commercial scale were reported by V. L. S. Charley in previous issues of this Report (1) and (2). Although much information is available, some of the methods employed would be unsuitable for domestic application. It was decided, therefore, to see how satisfactory a product could be obtained using only equipment available in most farmhouses or that obtainable at reasonable cost.

The tests carried out were of a preliminary character only.

Experimental.

The problems in apple juice production may be divided into the following groups :—

I.	Selection of suitable fruit.	III.	Clarification.
II.	Extraction of the juice.	IV.	Preservation.

I. Selection.

Culinary or dessert varieties, unsuitable for prolonged storage, would probably be the usual fruit available.

The following four varieties were used :—

Allington Pippin .. A dessert apple previously proving suitable for apple juice.
Bramley's Seedling .. An acid culinary variety.
Rev. Wilks .. .. A culinary apple, less acid than the former.
Worcester Pearmain .. A sweet dessert variety.

The flavour of the apple juices changed during storage. When it was first made, a juice prepared from the Rev. Wilks apples was regarded as the best of the series, but after six months' storage its flavour was considered to be " flat " and lacking in acid. On the other hand, after storage, Allington

Pippin apples were considered to give the best unblended juice, the Bramley's Seedling yielding a juice that was too acid, whereas the Worcester Pearmain was too sweet and insipid. A blend of the last two gave quite a pleasant product, with a suitable balance of sugar and acid.

II. Extraction.

A cider press, if available, is obviously the most suitable equipment for extracting the apple juice, but as many farmhouses would not have one, other methods had to be considered. In these tests, the juice was expressed by squeezing the apples, after preliminary softening, through several layers of butter muslin. It had previously been found that this method of extraction yielded approximately 75% of the juice which could be obtained if a cider press were used.

The following methods of softening the apples were tested, in each case the apples being washed and chopped without peeling or coring :—

(*a*) *Fermentation.* The chopped fruit was left in bowls in a warm room until slight fermentation had commenced. This generally occurred after 2–4 days.

(*b*) *Pectinol.* 0·2% of " Pectinol A " a pectin-decomposing enzyme, was mixed with the chopped fruit, which was then left as above for 1–2 days, until some separation of the juice occurred.

(*c*) *Yeast.* 0·5% of yeast (obtained from cider fermentation) was added in place of the pectinol and the fruit left for 2–4 days.

(*d*) *Cooking.* The fruit was simmered for 1–1½ hours until the apples were soft.

One quart of water to 8 lb. of chopped apples was added in treatments (*a*) (*b*) and (*c*), and 3 quarts to the same quantity in treatment (*d*).

Results. Both treatments (*a*) and (*b*) were satisfactory in softening the apple tissues sufficiently to allow the juice to be expressed, a yield varying between 3½ to 5¼ pints being obtained.

The addition of yeast appeared to impart an unpleasant flavour to the juice.

Cooking the fruit was not satisfactory alone, as the heat treatment extracted the pectin from the fruit, so that the resulting juice was very viscous and difficult to strain, and in spite of the addition of more water, a poor yield was obtained.

III. Clarification.

Three methods of clarifying the juice were tested :—

(i) The juice was allowed to drip through a felt jelly bag.

(ii) The juice was filtered through a Buchner funnel filled with paper pulp. (The vacuum necessary for this type of filtering could be obtained by a suitable attachment fitted to a domestic water tap).

(iii) The juice was filtered through a Buchner funnel fitted with filter papers coated with diatomaceous earth.

Results. The juice strained through a jelly bag remained opaque, but after storage for six months the juice separated into a brilliantly clear liquid with a very thick deposit in the lower part of the bottles.

Brilliantly clear juices were obtained after filtering by methods (ii) and (iii), though either a haziness of the juice or a deposit at the bottom of the bottles occurred after storage. The deposit was not generally as thick as that found in the juice which was given treatment (i). The addition of small

quantities of pectin to the clarified juice to prevent this deposit occurring during storage has been recommended (3), and further experiments would seem to be indicated.

IV. Preservation.

The clarified apple juice was in each case processed in bottles held at 180° F. for 20 minutes, since neither the " flash pasteurisation " nor the Seitz filtration methods, recommended commercially, could be adapted easily for domestic use.

Although this processing time has previously been found to be adequate, several bottles developed mould on storage, but this contamination may have occurred through the corks, which were boiled for ¼ hour before use but not steeped in sulphur-dioxide solution.

The disadvantage of processing for 20 minutes at 180° F. is that the juice tends to develop a " cooked apple " flavour, but some of the juices obtained in this series compared quite favourably with various apple juices at present being sold commercially.

Summary and Conclusions.

1. Preliminary experiments show that apple juice can be prepared domestically without recourse to expensive equipment.

2. In the selection of the fruit, a careful balance between sweet and acid varieties needs to be maintained.

3. The extraction of the juice could be carried out satisfactorily after leaving the chopped fruit until slight fermentation had occurred, or after the addition of a pectin-decomposing enzyme had reduced the viscosity of the juice. The addition of yeast to aid fermentation did not improve the juice, and cooking the fruit proved unsatisfactory.

4. A clear juice could be obtained by passing it under vacuum, through paper pulp or filter paper coated with diatomaceous earth, but in either case a haziness or sediment appeared during storage. If the juice was only strained through a felt jelly bag, a very heavy deposit formed on storage.

5. Preservation of the juice by heat treatment would be necessary.

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VEGETABLE PRODUCTION ON THE FARM.

By C. V. DAWE, M.Com., Ph.D. (Berkeley Square Advisory Centre).

Increase in Acreage of Vegetables.

It seems clear from discussions on post-war agriculture that, from international considerations, this country will have to relinquish a considerable part of its wartime cereal acreage. It is generally agreed that, on account of its climatic condition and the small scale upon which cereal growing can be undertaken, emphasis will have to be laid upon milk production, livestock farming and vegetable growing. Already, before the war, there were signs that farmers, as distinct from market gardeners, were considering the possibility of including a small acreage of vegetables in their farming rotation, but it is perhaps not realised how great has been the extension of the farm vegetable acreage during the war. All prices of agricultural commodities have risen

during this period, but, in general, it is probably true to say that the prices of vegetables have risen proportionately more than those of other agricultural commodities. Small wonder, therefore, that a farmer, having a suitable piece of land, has made perhaps his first attempt at growing a vegetable crop and, in the majority of cases, he must have been well satisfied. There is, however, another aspect in the case of the farmer having a mixed farm, since certain crops such as cabbage, savoys and brussels sprout stems form a valuable food for cattle and sheep and that part of the crop which was not harvested for human consumption enabled the farmer to eke out his supplies of fodder crops which were perhaps in short supply owing to pressure for wheat production.

It is now possible to publish the fact that between 1939 and 1944 the acreage of vegetables in this country, excluding potatoes, has risen from 280,000 to 466,000 acres, and it is clear that, since the recognised market garden areas are very limited, this increase of 186,000 acres must have come almost entirely from general farmers. The Bristol Advisory Province has expanded its vegetable acreage from 26,000 to 36,000 acres. Of this increase of 10,000 acres, Gloucestershire has contributed approximately 2,000, Herefordshire 1,500, Somerset 1,200, Wiltshire 1,000 and Worcestershire 4,300. In considering this increase, due regard must be paid to the area under vegetables in 1939. Of the five counties Worcestershire has always been the pre-eminent vegetable producing county, and it still accounts for two-thirds of all the vegetable area and, with the need to produce its share of corn and milk, it is not surprising to find that although it shows the greatest absolute increase, more than twice that of any one of the other four counties, its proportional increase is the least of all, being only one-quarter more than its 1939 acreage. Herefordshire trebled and Wiltshire doubled its pre-war acreage; the former now has 2,400 and the latter 2,000 acres under vegetables. Gloucestershire has increased by one-third, and Somerset by one-half during the war; the former county now has 6,800 acres and the latter 4,000 acres under vegetables.

BRISTOL PROVINCE.

ACREAGES OF THE UNDERMENTIONED VEGETABLES.

	1939.	1944.	Increase or Decrease. Actual.	Per cent.
Brussels Sprouts	7,403	7,723	+ 320	4
Cabbage, Savoys, etc.	2,306	4,589	+ 2,283	99
Cauliflower or Broccoli	1,338	2,048	+ 710	53
Carrots	360	966	+ 606	168
Parsnips	300*	935	+ 635	212
Turnips and Swedes	250*	707	+ 457	183
Beetroot	240*	661	+ 421	175
Onions	270	1,387	+ 1,117	414
Beans, broad Beans, runner and French	3,341	1,677 2,291	+ 627	19
Peas, green for market	7,654	10,284	+ 2,630	34
Peas, green for canning Peas, harvested dry	565	525 604	+ 564	100
Asparagus	1,252	593	— 659	— 53
Celery	40	60	+ 28	70
Lettuce	189	527	+ 338	179
Rhubarb	155	130	— 25	— 16
Tomatoes in open	59	625	+ 566	959
	25,722	36,340	+ 10,618	41

* Estimated.

Changes in Vegetable Cropping.

It is possible to see from the previous table the way in which acreages under various crops increased or decreased during the war. Of the eighteen crops listed only two show decreases, namely asparagus and rhubarb.

Omitting tomatoes, the acreage of which has been increased by nearly ten times, the largest relative increase is in onions, which in 1944 had risen by 414% above their pre-war acreage. This increase is followed by that of 212% for parsnips, closely followed by turnips and swedes, lettuce, beetroot and carrots. The two largest absolute increases are those for cabbage and green peas for market, which show gains of 2,283 and 2,630 acres respectively.

Possible Post-War Trends.

These present-day acreages will probably not be maintained after the war since the prices of vegetables will fall, indeed they have already begun to do so. It has already been made clear that the future agricultural policy of this country will be concerned largely with livestock farming and that cereal production will diminish considerably. Many farmers will, no doubt, revert to the practice of feeding livestock upon imported concentrated feeding-stuffs but, on the other hand, there will also be many who, having had the war experience of growing and selling vegetable crops and the experience of feeding them to livestock, will realise that it is possible to cash more of the productivity of their farm than they had hitherto thought possible. Operations for the production and cultivation of such crops will tend to be carried out more and more with the aid of machinery as distinct from the hand operations largely used on the market gardens in areas such as the Evesham Vale. As a result the yield per acre will, in general, be lower but the margin of profit per acre may be higher. Although, in wartime, maximum food production regardless of cost is the objective, in peacetime the farmer must consider carefully the margin between output and costs. Farm production of vegetables will also result in the crops being grown on clean ground since it will be an extensive system in a farm rotation rather than an intensive system confined to vegetable culture. The high incidence of pests and diseases which is prevalent in some of the old congested market garden areas may therefore not be experienced.

It is doubtful in fact whether the old market garden areas will be able to continue for many more years without some drastic reorganisation. Two reasons have already been mentioned, namely the prevalence of pests and the growing use of machinery. The third reason which may possibly be the most important is the present level of agricultural wages. From a survey carried out by this Department a few years before the war, it was found that, in spite of long hours of hard work, the occupier of a small market garden was earning less than the farm worker even when wages were considerably below those existing to-day. Agricultural wage rates are approximately twice pre-war rates, and although they may not go much higher they are not likely to fall. While the small market gardener may not employ any hired workers he will nevertheless find himself comparing his income with that which he could obtain as an employee on a farm, and he will realise that there are only two alternatives, namely to go on accepting a lower standard of living on his own holding or to relinquish that holding and obtain employment on a farm which can adequately remunerate his skill.

AGRICULTURAL "WEATHER" REGIONS OF ENGLAND AND WALES.

THE INTEGRATION OF SUMMER RAINFALL AND TEMPERATURE DATA.

By D. A. OSMOND.

Much attention is being paid, at present, to the question of classifying land in such a manner as to bring its agricultural potentialities into prominence. Several systems have been developed, particularly in America, for "assessing the value of" or "giving a rating to" agricultural land, but such systems are generally concerned with the soil factor only and tend to neglect the climatic factor which may, in some instances, be of greater importance for the production of particular crops.

This apparent neglect has been recognised in a statement by J. J. Haggerty and A. M. Meyers (1). "Ordinarily the soil survey reports contain a brief treatment of average climatic conditions and call attention to some of the more striking climatic causes of crop failure, such as drought, hail or frost. An adequate climatic analysis would place attention not on the average conditions of climate, but upon the expected range of conditions and the frequency or rate of occurrence of conditions favourable or unfavourable to plant growth and plant life. The agronomic, and hence the economic, implications of climatic variations are tremendous."

Possibly two of the reasons for this seeming neglect are (1) the difficulty of summarising in a simple form the mass of data which the meteorologists provide, and (2) the fact that agriculturists are not quite as interested in climate as in the weather, which may be defined as the climatic conditions over a short period.

Separate maps showing the distribution of many climatic factors are available, but the weather is the integration of all these factors. Among the numerous factors, rainfall and temperature are two of the most important, but while maps showing the mean monthly rainfall and the mean air-temperature can be produced, to study the variations of both over a period of six months, twelve maps would have to be consulted. Furthermore, while the data show, for example, that one place has a higher rainfall than another, there is no satisfactory criterion as to whether this difference is significant or not.

It was felt that if a single map could be produced combining some of the relevant data, than descriptions and comparisons of weather from an agricultural standpoint would be simplified.

Method of Approach.

As a first approximation of agricultural "weather" attention has been given to the data for mean monthly rainfall and mean monthly air-temperature for the six summer months, April to September, and the temperature data for March. These data have been selected as being of most interest agriculturally. The following assumptions have been made :—

1. The soil contains sufficient moisture at the end of March for germination to start.

2. Other conditions being favourable, germination can begin when the temperature is about 42° F. In default of sufficient data on soil temperatures, air-temperature has been used instead.
3. If the average weather conditions of England and Wales are suitable for crop growth, then conditions which are significantly different from the average may be better or worse.

Inspection of the data in the Book of Normals (2) reveals that mean monthly air-temperatures at or above 42° F. first occur in March and this provides the first main division of England and Wales into (1) areas having a cold March, with mean monthly air-temperature below 42° F., and (2) areas with a warm March in which the mean monthly air-temperatures are at or above 42° F.

For the sake of simplicity the discussion which follows is limited to a consideration of rainfall data only, but the arguments are equally applicable to temperature data. The term " average " rainfall refers to the average of the mean monthly rainfall during a 33 or 15 year period over England for the six months considered and has been calculated from the data of 100 stations in England, obtained from the Monthly Weather Report of the Meteorological Office for 1939. This (six months) average (A) is found to be 2·19 in.

The same data were subjected to statistical analysis to determine the standard deviation (S.D.). If $\pm x$ is the difference of any station in any month from A, then in order that A $\pm x$ (the rainfall) shall be significantly different from A at the 10% point, $\pm x$ will be S.D. x 1·282. The figure 1·282 is obtained from Fisher's " Table of x " and gives the probability of values having both positive and negative deviations at P = 0·2. Since interest is centred on positive deviations at one end of the scale and negative deviations at the other, the value of P is divisible by 2 and hence the figure 1·282 can be used and the probability raised to P = 0·1.

For the mean monthly rainfall the significant difference is ± 0·70 in., and therefore stations with a mean monthly rainfall of 2·19 + 0·70 = 2·89 in. or more in any month are termed *Wet* for that month, and those with a mean monthly rainfall of 2·19 — 0·70 = 1·49 in. in any month are termed *Dry* for that month. Stations whose mean monthly rainfall fall between these values are termed " Moist."

By treating the mean monthly air-temperatures in the same way, the (six months) average is found to be 55·7°F. and the difference for significance at the 10% point is ± 6·86° F. Therefore *Hot* stations are those whose mean monthly air-temperatures are at or above 62·5° F., and *Cold* stations have mean monthly air-temperatures at or below 48·8° F., while those stations falling within these limits are termed *Warm.*

By inspecting the data it is easy to see which stations can be termed Wet, Moist or Dry, and Hot, Warm or Cold in any of the six months considered. If all the stations are plotted on a map, with a symbol to indicate in which months they are Wet or Dry and Hot or Cold, it is possible to enclose all those stations having, for example, in addition to a warm March, a cold dry April, and warm wet August. In this way " Weather Regions " can be delimited roughly, each of which is unique in its combination of rainfall and temperature.

Since the regions are built up from data which are significantly different from the average at the 10% point, there is some reason for their being so. The most obvious causes of these differences are topographical features, and if the Weather Regions are drawn on a contoured map, the connection between certain regions and the contours becomes apparent. In order to obtain a

more correct delimitation the data of over 300 stations, given in the Book of Normals, were inspected and included (without further calculation) on the map.

By this method it is possible to divide England and Wales into twenty-eight "weather regions," each with its unique characteristics as shown in Table I. In the table :—

W indicates mean monthly rainfall of 2·89 in. or more.
D ,, ,, ,, ,, ,, 1·49 in. or less.
H ,, ,, ,, air temperature of 62·5° F. or more.
C ,, ,, ,, ,, ,, ,, 48·8° F. ,, less.

and the blank spaces indicate average conditions, *i.e.* the mean monthly rainfall and air-temperature fall within their respective limits. Regions 1—10 have a cold March and regions 11—28 have a warm March.

To a certain extent the table also indicates the monthly variations over the season. It is well known that April is generally a cold month and August is frequently wet. Inspection of Table I reveals that of the twenty-eight regions, twenty have a cold April and seventeen have a wet August, and in addition that twelve regions have a wet July and eleven a wet September.

TABLE I.

Region No.	March.	April. Rain.	April. Temp.	May. Rain.	May. Temp.	June. Rain.	June. Temp.	July. Rain.	July. Temp.	August. Rain.	August. Temp.	September. Rain.	September. Temp.
1	COLD MARCH	W	C	W		W		W		W		W	
2			C			W		W		W		W	
3			C					W		W		W	
4			C					W		W			
5		D	C	D	C								
6			C							W			
7		D	C										
8			C										
9		D											
10			C	D	C				H		H		
11	WARM MARCH												
12			C										
13			C						H		H		
14			C								H		
15			C							W			
16			C					W		W			
17			C					W		W		W	
18			C			W		W		W		W	
19			C	W		W		W		W		W	
20			C							W		W	
21		D	C										
22		D											
23										W			
24										W		W	
25		W				W		W		W		W	
26		W		W		W		W		W		W	
27		W	C	W		W		W		W		W	
28								W		W			

MAP SHOWING WEATHER REGIONS (SUMMER MONTHS) OF ENGLAND AND WALES.

For key to numbers, see text.

Geographical Distribution of the Regions.

Region 1 includes the Lake District, the highest land in the Pennine Chain, the Peak District, Snowdonia, the high mountains of Central Wales, Dartmoor and Exmoor.

Region 2 occurs on the east side of Lancashire.

Region 3 occupies the west coast of Cumberland and Westmorland and central Lancashire, together with three smaller areas (1) around Bellingham, (2) Appleby and (3) Llangammarch Wells in Wales.

Region 4 covers practically the whole of the eastern side of the Pennine Chain as well as a small area east and south-east of Manchester.

Region 5 is found in two small areas, viz. around Berwick-on-Tweed and around Dungeness.

Region 6 occupies the country north and north-west of Newcastle-on-Tyne, a smaller area including Harrogate and Ripon, and a larger area fringing the east side of the Peak District and stretching south of Bradford to near Burton-on-Trent. The high land of the Longmynd Hills and South Shropshire falls into this region. A small area stretches east from Salisbury. Cirencester is included and it is probable that the region covers the higher land of the northern Cotswold Hills. The west coast of Lancashire also falls into this region.

Region 7 occurs in scattered patches mainly on the east coast, viz. (1) Tynemouth, (2) Skegness, (3) the north and part of the east coast of Norfolk. It is also encountered around Worksop and in a larger area reaching from Nottingham to Sutton Bonington.

Region 8 covers practically the whole of Yorkshire and Durham together with the southern parts of Lincolnshire and Nottinghamshire. Birmingham, Coventry and Rugby are also included. The Chiltern Hills, Marlborough and Salisbury Downs together with the North Downs and a small area around Reading fall into this region. It also occurs around Cheltenham and Gwernyfed Park in Wales.

Region 9 covers the northern parts of Lincolnshire and extends northwards over the Humber estuary to Lowthorpe. Smaller patches occur around Scarborough, Whitby, Middlesborough and Bamburgh.

Region 10 occurs only around Felixstowe, Clacton-on-Sea and Southend.

Region 11 occupies practically the whole of the central part of Southern England.

Region 12 fringes almost all the south coast and a narrow strip of the north-west Cornish coast.

Region 13 is found only around Southampton.

Region 14 borders the Thames estuary and stretches westwards as far as Farnborough. Small areas include Weymouth, Swansea and a patch north of Newton Abbot.

Region 15 covers Anglesey and the north coast of Wales, the extreme west of Pembrokeshire, the plain of Glamorgan and a small area around Newtown. In England it occurs on the Malvern Hills and on the Cotswold Hills, linked through Dorset to central Devonshire. Plymouth and the Tamar Valley also fall into this region.

Region 16 is found as a narrow strip including Manchester and Stoke-on-Trent.

Region 17 extends over central Cornwall, with a detached area near Newton Abbot. Most of Monmouthshire and Pembrokeshire are also included.

Region 18 occurs in two areas in Wales, along the west and south-west coasts.

Region 19 covers most of Radnor.

Region 20 is found in three separated areas (1) the Cardigan Valley, (2) Northam-Torrington in Devon, and (3) Falmouth.

Region 21 covers the inland parts of the coast near Chelmsford in Essex to Rendlesham in Suffolk.

Region 22 occupies the slopes to the south of the Chiltern Hills and the whole of the Fenland.

Region 23 extends from the south-west corner of Lancashire, through the Cheshire Plain to north Shropshire and includes Flintshire and part of Denbigh. The west side of Herefordshire and part of Monmouthshire fall into this region. Smaller areas are found around Bromsgrove and on the South Downs.

Region 24 only occurs around Penzance.

Region 25 includes the Mendip Hills and part of the Dart Valley.

Region 26 covers Bodmin Moor.

Region 27 occupies most of Central and parts of South Wales.

Region 28 is found along the south Cornish coast.

While the distribution of certain regions can be correlated with the heights above sea level, in other cases the reason is not so obvious and other factors certainly influence the distribution.

The association of the ten regions, 1, 2, 3, 4, 17, 18, 19, 25, 26, and 27 with high land subjected to warm wet wind from the south-west is only to be expected. Regions 10, 13 and 14 appear to be associated with estuaries facing south or south-east. Regions 6 and 8 with cold March and April, with or without a wet August, are associated with exposed high land. Undoubtedly the amount of exposure of or shelter afforded by high land from the prevailing wind has much to do with the weather experienced in any locality.

Conclusions.

1. It is possible to integrate the mean monthly rainfall and mean monthly air-temperatures and the resultant may be described as a weather region.

2. Each weather region is characterised by unique weather conditions.

3. By plotting the weather regions on a contoured map, they can be delimited geographically.

4. The comparison of the weather in different areas is facilitated.

5. Attention is drawn to a range of conditions, rather then to the average climatic conditions.

6. Although the exact limits of any region are open to correction, yet the map is sufficiently correct to afford a good guide to undertakings in which some knowledge of the weather is necessary.

Acknowledgment.

I should like to express my thanks to Dr. W. Plant, of the Research Station, Long Ashton, for the interest he has taken and for the assistance given in the statistical analysis.

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AN INDEX FOR USE IN THE REGIONAL CLASSIFICATION OF LAND FOR AGRICULTURAL PURPOSES.

By D. A. OSMOND.

In most systems of rating or assessing the value of an area for agricultural purposes the final answer is given either as a letter or a number, obtained by processes involving a mental integration or a mathematical calculation of the factors which make the area first-class or otherwise. In such systems there is no clue to which factors are operating beneficially or adversely, neither is any indication given as to which, if any, of the adverse factors can be altered.

The system now proposed is here used over large areas, but can be applied to smaller areas, such as single farms (possibly with slight modifications). It is based on the concept of regions, each of which is distinct, but which can be compared with the others and classified at a later stage.

Each region is defined in terms of the three basic factors of Site, Soil and Climate which the agriculturist has to deal with in growing crops, together with a fourth factor—the Development Factor. This term is used to signify both the influences of Man's activities and of such Natural phenomena as are not included in the first three factors. Thus a region may be excellently sited, have a first-class soil and possess a good climate, but owing to smoke damage from a large heavy industrial town or because a natural forest covers the area, it may be of low value or even useless for agricultural purposes.

For the purpose of obtaining the index, each factor is divided into three grades and numbered in order of merit. The complete scheme is as follows :—

	Good	Intermediate	Poor
Site Factor	1	2	3
Soil Factor	1	2	3
Climatic Factor	1	2	3
Development Factor	1	2	3

Each region is defined by a four-figure index, and it is essential that the figures should always be given in the order of Site, Soil, Climatic and Development Factors. As an example, the index 1213 indicates that the region has a good site, the soil is moderately good, climate is good but either Man's Influence or some Natural Condition is " poor," and from either of these causes the area may be either capable of growing only a restricted range of crops or may be of little importance to agriculture.

It is possible to define eighty-one regions in this manner ranging from 1111 to 3333 and the form of the index provides some guide as to why the region is of more or less importance to agriculture. In the above example, it can be deduced that if the conditions indicated by the figure 3 can be remedied, the area would become of use to agriculture and therefore its retention for that purpose should be considered in planning schemes.

Conditions Influencing the Numbering of the Factors.

It is not possible to give a list of all the points to be taken into account in deciding the number to be given to each factor and only a few general examples are given.

Site Factors. Under this heading the chief points to be considered are elevation, slope and topography. Points of less importance but which may have a great influence on the utilisation of an area are liability to flooding, aspect, and the natural water-supply as determined by ponds, springs, steams, etc.

" Good " sites include gentle undulations, gentle to moderately steep slopes, small flat areas. The height above sea-level should not be too great. The aspect should be favourable, and the natural water supplies be adequate. Air-drainage should be free so that frost-pockets do not occur.

" Poor " sites include very steep undulations or hummocky areas, very steep slopes, and large, flat low-lying areas. The elevation is such that it may be the limiting factor in the agricultural use of the region. Areas which are liable to flooding for long periods either from surface water or river flooding would be included here. Air-drainage is poor and frost-pockets occur. The aspect is unfavourable and the natural water-supplies are inadequate.

Sites would be indicated as " intermediate " which have some points included in " good " but also some which are deleterious.

Soil Factors. There are many points to be considered when soil factors are being numbered, and the best soils should possess properties which enable high yields of a variety of crops to be grown with the minimum expenditure of capital and labour. Such soils should be (*a*) sufficiently deep, (*b*) able to maintain an adequate supply of water to the crop at all seasons and suffer neither from drought nor water-logging, (*c*) endowed with a high natural supply of nutrients available to the crop, and (*d*) easily worked to produce a good tilth.

" Poor " soils, on the other hand, are shallow, liable to drought or water-logging (impeded drainage in the profile as distinct from poor site drainage).

Soils to be numbered 2 may have some properties of the " good " soils but combined with some of those of the " poor " group.

Climatic Factors. While there are many points which comprise the climatic factors of a region, two of the most important agriculturally are the rainfall and temperature during the growing season. For the moment, the use of the " Weather Region " map (see p. 216) is suggested as being a sufficiently good guide to the weather conditions over large areas. The map covers only England and Wales, and the Weather Regions are grouped so that " Good Climate " (numbered 1) includes Regions 11, 12, 14, 15, 16, 20, 22, 23, 24, and 28, while " Poor Climate " (numbered 3) includes Regions 1, 2, 3, 17, 18, 19, 25, 26, 27, each of which has a minimum of three wet months (*i.e.* 2·89″ of rain or more per month from April to September). " Intermediate Climate " includes Regions 4, 5, 6, 7, 8, and 10 with a cold March and cold April, 9 with cold March and dry April, 13 having hot July and August, and 21 with cold March and cold dry April. In addition consideration should be given to the nature of the prevailing wind and the season in which it occurs, as a cold seasonal wind may be the cause of long cold periods together with shorter frost periods, which are distinct from the frost-pockets considered under Site Factors.

Development Factors. The properties of a region to be considered under this heading may be, in general, divided into two classes (*a*) Natural Influences and (*b*) Man's Influence.

In a newly-developing country "Natural Influences" will mainly determine the number to be given, *e.g.* Forested land would be numbered 3, as against Prairie Land, which is ready for agricultural development, and which would therefore be numbered 1.

In older countries, most of the land suitable for agricultural development has been used for that purpose so that "Natural Influences" may be disregarded over much of the country and the number given to the regions will be mainly determined by "Man's Influence."

It is not possible to discuss all the points involved in this factor, but a few instances are given. The guiding principle is that the *effect* rather than the cause is marked according to whether it is good or bad. Two simple examples where the Development Factor is numbered 1 are as follows :—(*a*) A region in which the standard of farm management is high so that soil fertility is at least maintained, if not actually increased. A case in point is the Vale of Evesham, in which several soils are naturally poor and would be numbered 2, and in some cases 3, and the region would be given the index 121X or 131X. Various circumstances have made it profitable to cultivate the region intensively, with a high standard of farm management and the Development Factor is numbered 1 . The complete index thus being 1211 indicates that the region is very adaptable to agricultural development, but that the soil is only moderate and may have its limitations (as it has).

The second instance is the establishment and control of a regional drainage scheme, which has caused an area otherwise useless agriculturally to be brought into a first-class region, *e.g.* the Fenland. Before the various drainage schemes were set in operation, the index would be 3213—the first figure 3 standing for poor site (large, flat and low-lying), 2 for an intermediate soil (peat in places, but probably with good nutrient status), and last figure 3 indicating a poor "Natural Influence." By the drainage schemes, the water-table is controlled, the soil is thereby improved, the Development Factor is changed to 1, indicating "Man's Influence" as good and the present index would therefore be 3211 or 3111.

Examples of "bad" Development Factors are (*a*) the felling of woodlands on slopes without reafforestation or grassing-down, leading to loss of surface soil by erosion. (*b*) The neglect and subsequent failure to maintain a regional drainage scheme. (*c*) The industrial development of the region with adverse effects on agriculture.

The effects of established industries or the introduction of industries on farming are manifold and various. The population of the area will be raised and the demand for produce of a different class and quality will increase, probably with the result that the type of farming will change, generally towards a more intensive form, near the town if possible. At the same time the standard of farming will be raised at some distance from the town. Instances of these conditions are to be found in the development of London and Birmingham. While their growth has ruined some of the adjacent land, yet part of Kent and the Lea Valley in the first case, and the Vale of Evesham in the second, have mainly attained their present status because of the presence of a ready market for high-grade produce.

It should be remembered that a *region* is being considered and not individual fields, so that although some of the latter in a particular region are "good," the region, considered as a whole, may be "poor." Also in numbering a factor, the main characteristic and its "severity" should determine the number. Thus a soil may be quite shallow, fairly well-drained

and have a fairly good nutrient status. The shallowness may be the main character and the soil should be numbered 3.

Use in the Classification of Land.

The index is based on a consideration of some characters of the land itself and is a convenient method of representing these facts, but it is not a complete classification. Rather does it indicate the possibilities of the agricultural uses of each region, and the best *regions* are those which will produce the highest yields of the greatest variety of crops with the minimum expenditure of capital and labour. Poorer regions either produce low yields of a variety of crops or good yields of a small number of crops. When a sufficient number of indices have been studied, they can be grouped into simple classes such as A, B and C, in which Class A would include regions with indices 1111, 1112, 1121, 1211 and 2111 for instance, and regions with these indices should be comprised of land of the highest importance to agriculture.

Regions with low indices (*e.g.* 3212 and 3312) have a more restricted use, and although the land may be classified as C, it may still be of much agricultural importance by virtue of its high productivity of one or two crops.

Land Quality would be shown thus :—

	Index (Site, Soil, Climatic, Development Factors)	Category (A, B or C)
Examples :	1112	A
	1211	A
	2221	B
	2121	B
	3212	C
	3333	C

In order to show how the scheme may be applied, the accompanying map of the Somerton-Langport area in Somerset has been constructed.

The soils have been mapped on the 6″ to 1 mile scale and the boundaries of the various soil series are indicated by thin lines. The soil series have been rated as 1, 2 or 3, and the data for the site have been treated in a similar manner. The whole of the area is included in Region 11 of the Weather Map and the Climate Factor is therefore 1.

Although on some individual farms the standard of management is high, yet taking the area as a whole, management is of an intermediate quality. Furthermore, no specialised crops are grown and only small parts of the area are adapted to such crops. There are several good main roads connected by moderately good second-class roads and a main railway line to London passes through the area. In general water supplies to farms are adequate, although in some parts the water supply in fields may be rather poor. Taking these facts into account, the Development Factor is taken as 2.

The indices of the various areas are shown on the map, and the thick lines show how groups of indices may be included in the larger classes A, B and C.

INDEX. CLAS

1112, 2112	A
1212, 1312, 2212, 2312	B
3212, 3312, 3313	C

Soil Boundaries —

Class -

Scale:-
1 inch = 1 mile.

N

Somerton–Langport Area (Somerset) showing Indices and Classes.

From a consideration of the indices it is possible to indicate areas which might be raised in productivity. The index (1312) given to the large area west and south-west of Somerton indicates that sites are good, the soils are poor (shallow clay over limestone), the climate is good, but that the development factor is intermediate. This last possibly might be raised by improving the standard or even changing the system of farming, by additional water supplies, or even by improving communications and social amenities. This, therefore, is a large area to which attention might be given to see if the agricultural potential could be raised. A second area which merits attention is the Sedgemoor region. The index is 3313, but if a regional drainage scheme were set in operation, together with adequate methods of controlling the drainage and water table in smaller areas, there is no apparent reason why the area should not be improved so that the index would become 3212 or 3111, provided that the peat is of a satisfactory nature and that the standard of farming can be raised.

This area may be compared with that lying south-east of Langport and having the index 3212. The soil factor (2) is due to the soil being a heavy clay, which is not easily drained and which is also liable to flooding from the river. The latter may be overcome, but still the soil factor would remain 2. A chance of amelioration lies in the development of better farming coupled with the provision of better communications. It is apparent that this area does not afford the prospect of much improvement, and it will probably remain a fairly highly productive region due to the quality of the grass it can produce.

Conclusions.

1. An index is proposed based on important objective characters affecting agricultural utilisation of the land.
2. It can be used as an aid in classifying land.
3. It indicates the nature of the advantages and disadvantages of each region.
4. It enables comparison of one region with another to be readily made.

REPORT ON ADVISORY WORK, 1943-44.

The total of advisory letters sent fell from 10,880 in 1942–43 to 8,262 in 1943–44. The table below lists the county totals together with the figures for the preceding five years.

ENQUIRIES SUBMITTED TO THE DEPARTMENT, 1939—1944.

	Year ended September 30th.					
	1939	1940	1941	1942	1943	1944
Gloucester (including Bristol) ..	2264	1965	2491	2676	2908	2231
Hereford	556	182	196	729	771	438
Somerset	1117	1403	1479	2039	2491	2076
Wiltshire	1586	970	1410	1372	1691	1389
Worcester	677	656	1010	1506	1491	699
Other Areas	1516	2686	1776	2030	1528	1429
Totals	7716	7862	8362	10352	10880	8262

Staff Changes.

Agriculture and Agricultural Chemistry.

Appointments :—Mr. R. Stewart, B.Sc., Ph.D., as Advisory Chemist; Mr. K. Shaw, B.Sc., as Senior Analyst ; Mr. R. D. Russell, B.Sc., as Field Assistant.

Resignation : Miss L. Grenfell, B.Sc., Field Assistant.

Dairy Bacteriology. (*National Milk Testing and Advisory Scheme*).

Appointments : Miss B. Glason, B.Sc., N.D.D., as Area Supervisor ; Miss E. I. Garvie, B.Sc., as Area Supervisor ; Miss G. A. Ward as Records Officer.

Resignation :—Miss M. S. Sellers, N.D.D., Area Supervisor.

Agricultural Economics.

Appointments : Mr. V. M. Wadsworth, B.Sc., as Senior Scientific Assistant ; Mr. R. C. Broughton, N.D.A., as Junior Scientific Assistant ; Mr. G. H. Caudwell, N.D.A., as Junior Scientific Assistant.

Resignations : Mr. L. Hirschberg, Eng.Agr., Junior Scientific Assistant ; Miss P. Brice, Recorder, National Farm Survey.

Death : Mr. L. A. C. Cook, B.A., Senior Scientific Assistant.

Veterinary Science.

Appointment :—Mr. B. Rimmer, M.R.C.V.S., as Assistant Veterinary Investigation Officer.

Resignation :—Mr. R. W. Roach, B.Sc., M.R.C.V.S., Assistant Veterinary Investigation Officer.

Economic Entomology.

Appointment :—Mr. F. Raw, B.Sc., as Junior Scientific Assistant (Wireworm Survey).

Resignations :—Miss M. E. F. Jones, B.Sc., Team Leader, Wireworm Survey ; Miss B. M. Smith, Field Assistant, Wireworm Survey.

Economic Mycology.

Resignation : Mr. C. J. Hickman, M.Sc., Advisory Officer, Evesham Field Laboratory.

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